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NSF AUTHORIZATION

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE,
TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION UNITED STATES SENATE

NINETY-NINTH CONGRESS

SECOND SESSION

ON

AUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION

MAY 15, 1986

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NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, MAY 15, 1986

U.S. Senate,
Committee on Commerce, Science, and Transportation,
Subcommittee on Science, Technology, and Space,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:05 a.m., in room S-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

Staff members assigned to this hearing: Cassie Phillips, staff counsel; and Pat Windham, minority professional staff member.

OPENING STATEMENT BY SENATOR GORTON

Senator Gorton. National Science Week in 1986 is a good time for reflection. Ten, twenty, or fifty years from now, historians will look back at 1986 as a turning point for American science and engineering.

After World War II, we made a national commitment to scientific research. The Soviets launch of Sputnik led us to increase sharply our support for science and engineering to meet the challenge of competition and scientific achievement.

Today the loss of the space shuttle *Challenger* and the destruction of the nuclear powerplant in Chernobyl are tragic events, discouraging the scientists throughout the world. As dark as these times may seem, however, they offer us the opportunity to renew our commitment to science and engineering and to proceed with programs better than those that went before.

We, in the Congress, and you, in science and engineering, must make a critical assessment of our priorities, the adequacy of our investment of the quality of our execution in science and in engineering.

Recent events remind us that we can never finish the job of scientific investigation. Our commitment in science is to discover, change, challenge our assumptions, and to build steadily on the successes and failures of the past.

The real secret to scientific and technological success is hard work, patience, and faith that the payoffs, though not always obvious, will be worth the wait.

Fortunately, for the National Science Foundation and for its programs, Congress and the administration recognize the importance of basic research. The budget request for the Foundation can only be described as generous in these days of Federal budget cuts.

Thus far, congressional support for that budget has been strong. My colleagues and I on the Senate Budget Committee were able to see that the Senate budget resolution supports the administration's request for the National Science Foundation.

It protects the Foundation by supporting NASA's programs as well. The House has marked up at a subcommittee level a budget for the Foundation which is at the President's request, although with some differences in the allocation of funds.

I have opening statements from Senators Pressler, Hollings, Riegle, Gore, and Rockefeller that I will insert in the record.

[The statements follow:]

OPENING STATEMENT BY SENATOR PRESSLER

I commend the distinguished chairman for conducting this hearing today. The National Science Foundation plays an important role in several issues I would like to address in some detail. Unfortunately, a prior scheduled commitment makes it impossible for me to be present this morning.

As my colleagues know, I have introduced "The Strategic Defense Education Act of 1986," S. 2117, aimed at rebuilding our fragile scientific research base. University research facilities and equipment desperately need renovation and modernization. The number of American students pursuing graduate degrees in areas of national need is inadequate.

NSF has made great strides in improving the state of American research. I look forward to continuing to work with NSF on this problem and will be submitting a thorough statement for the record, as well as questions for today's witnesses.

In addition, we have been working closely with the NSF and other agencies on the Continental Scientific Drilling Program [CSDP]. I will also be submitting comments and questions on this issue.

Thank you.

OPENING STATEMENT BY SENATOR HOLLINGS

Mr. Chairman, this year we face very difficult budget decisions. Yet we also continue to face a very strong economic challenge from abroad—a challenge that can be met only through superior technology and a tougher pro-competitiveness policy. We must, as a nation, learn how to compete in this new global economy. Support for basic research and new mechanisms to transfer that research quickly to American companies must be part of that strategy.

Today the Commerce Committee continues its review of the President's FY 1987 request for the National Science Foundation. That budget request is generous, a hefty 13-percent increase over the 1986 level. I look forward to reviewing that proposal and examining the testimony of today's witnesses. In particular, I look forward to working with you and our colleagues on this Committee and the Labor Committee to fashion an NSF bill that meets the needs of our times.

OPENING STATEMENT BY SENATOR RIEGLE

Mr. Chairman, today's hearing will focus on the priorities and operations of the National Science Foundation. I am pleased that NSF's proposed budget for fiscal year 1987 includes an increase over this year's funds. As I have said before, I view NSF as the lead agency in our efforts to maintain and enhance industrial competitiveness in world markets. Basic research is the key to new industrial processes and applications. It is not only the key to the economic future of industrial states such as Michigan but also for the nation as a whole.

I will examine this budget request carefully, particularly in light of these economic needs. I know that Mr. Bloch has strengthened the Foundation's commitment to basic research in the engineering sciences and in other areas, such as chemistry, that hold great economic promise. But the fact remains that only a relatively small portion of the total NSF is devoted to engineering. As the Young Commission said a year ago, we must invest more in civilian basic research which has industrial competitiveness as its goal. We must do better, and NSF must play a major role in the necessary effort.

Mr. Chairman, before concluding I want to add that I am very pleased that the Commerce Committee and the Labor Committee have reached an agreement regarding the annual NSF authorization bill. Your leadership and the goodwill of other members of both committees have finally broken an unfortunate stalemate. I look forward to working with you and our colleagues to fashion the best possible bill this year.

I also look forward to this morning's hearing and to the testimony of our distinguished witnesses.

OPENING STATEMENT BY SENATOR GORE

I am pleased that this subcommittee is conducting an authorization hearing on the National Science Foundation. I have long been a supporter of NSF's many programs and believe that support for basic research is one of government's most important contributions. The money we invest today will pay us back many times over—in everything from a better understanding of our planet to improved economic competitiveness. Research funds are the seed money of our future.

In a time of budget constraints and the threat of automatic cuts mandated by Gramm-Rudman-Hollings, NSF has fared well. Both the budget submitted by NSF and the Senate Budget Committee's bipartisan budget resolution have called for substantial increases in funding. This strong support for NSF's continued growth is the result of NSF's impressive leadership in the development of science and engineering in this country.

I'm particularly looking forward to learning more about NSF's plans to advance our knowledge in the areas of biotechnology, global geosciences, computational science and engineering. NSF calls them "areas that are uniquely poised for important advances" and I agree.

Scientific progress in biotechnology continues at a frantic pace. Some estimate that our knowledge doubles every six months. Each day reveals more evidence of the tremendous potential of biotechnology to reshape the world as we know it. No other technology has advanced so quickly.

NSF is to be commended for looking ahead to the commercialization of biotechnology and the need for establishing multidisciplinary teams to meet the challange of the future. The successful commercialization of biotechnology will depend on a strong commitment to basic research and the ability of researchers to anticipate and respond to the needs of industry.

Industry emphasizes today's opportunities. Basic research tends to focus on tomorrow's new ideas. If we can bring them together, we can keep the U.S. a world leader in technology innovation.

NSF's supercomputer network, NSFNET, provides us with a good example of how industry can benefit basic research. NSF has supercomputers that need to communicate to each other. Industry has new fiber optic networks which may provide a state-of-the-art communication system for NSFNET. The possibilities of such a marriage are endless.

I am pleased to be counted as a NSF supporter, but there is one program which still concerns me. Last year, NSF proposed the elimination of the Ethics and Values in Science and Technology (EVIST) Program. In response to my deep concern and the concern of a number of my colleagues here in the Senate, NSF agreed to continue EVIST by encorporating it into programs sponsored by the various NSF Directorates.

What new programs has this modified version of EVIST produced? What are NSF's plans for the future of EVIST type programs? What is the current and planned level of funding for the evaluation of the role of ethics and values in science and technology?

The concerns I expressed last year are still valid. I believe that programs like EVIST must be preserved. The amazing advances in science are surpassing the ability of our social, ethical, and legal institutions to cope with them. Unless we begin to search now for solutions to the serious ethical dilemmas that modern science is creating, we have no moral basis for our support of science.

Mr. Chairman, I am pleased to have the opportunity to hear from such a distinguished group of witnesses. I look forward to learning more about NSFs plans for the future and how the science community views current priorities in basic research.

OPENING STATEMENT BY SENATOR ROCKEFELLER

Mr. Chairman, those of us who consider research and education one of our top priorities cannot help but be pleased with the 1987 budget request for the National Science Foundation.

Indeed, there are few Federal agencies or programs, other than military, which have been slated for a net increase of 8% in the Administration's 1987 budget request. I must say that while the Administration and I do not see eye-to-eye on many issues, when it comes to the need to increase funding for basic research at NSF we are in absolute agreement.

In an era of tight budgets, however, Federal spending for basic research is considered a luxury by many. For example, people are increasingly questioning whether industry, rather than the Federal Government, should fund the research that ultimately benefits them. I am convinced that allocating funds for basic scientific research is not a luxury but a real need, it is an investment in our future and is critical to ensure our survival as a technological Society.

However, the current economic situation has made it very evident that we need to closely monitor our expenditures. Indeed, with the budget deficits looming over us support for basic sciences becomes a matter of defining priorities, detemining what areas of science and engineering should be stressed and which could be curtailed. This is not simple or easy. The decisions that we make will inevitably set the course of the country's scientific future. We need to determine that the dollars we propose to spend be spent wisely and equitably.

Mr. Chairman, overall I am pleased with the funding priorities set forth in this year's budget proposal for NSF. I was particularly reassured to see NSF's continued support for the EPSCOR program and for training programs in math and science education. I also welcome NSF's emphasis in the areas of biotechnology and computational sciences, as well as the new engineering centers. Investment in these areas are, in my opinion, of critical need to maintain our international competitive edge and will help ensure our continued leadership in these fields.

Mr. Chairman, I would take this opportunity to express my concern about the importance of obtaining an equitable distribution of our research funds. No one can argue that investing our Federal dollars in well established research institutions is wise. However, there are other criteria which in my opinion, should be met as well. Criteria such as geographic distribution, accessibility to minorities and potential scientific excellence are just as important. They are important because they seek to breach the ever-broadening gap between those states who have traditionally excelled in academic pursuits and those who are putting their best efforts forward to attain excellence.

The NSF has shown its concern for these issues by embarking in the EPSCOR program. In fact, my State of West Virginia was one of the first five States to benefit from this program. I am pleased to see this program will continue in other states and I commend NSF for its initiative in this area.

Nevertheless, I would argue that States like West Virginia, which have been traditionally underrepresented in NSF's allocation of funds do not merely need a one time "shot in the arm" influx of funds. If they are to establish themselves as strong scientific and academic centers they need continuous and concerted support for research efforts. These efforts must come, not only from NSF, but from the State and the community itself.

Mr. Chairman, we are a country which is proud of its people and the potential they have. In determining our priorities let us not forget that we may very well receive a larger return for our dollar when we invest in these untapped resources. I urge NSF to support programs like EPSCOR and to continue to search for avenues to equitably distribute its funds.

Thank you very much.

Senator GORTON. The Senate Committee on Labor, I understand, will report a bill next week. I look forward to receiving that legislation, which will be referred to the Commerce Committee for 30 days under an agreement we reached last year.

I should like to note that the chairman of that committee, Senator Hatch, along with its ranking member, Senator Kennedy, have been a pleasure to work with in support of the Foundation and of its programs.

With that, of course, we are happy to start our hearing today with the testimony of Mr. Bloch, the director of the National Science Foundation. You are welcome here and we will be delighted to hear from you.

STATEMENT OF HON. ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION, ACCOMPANIED BY DR. ROLAND SCHMITT, CHAIRMAN, NATIONAL SCIENCE BOARD

Mr. **Bloch**. Thank you, Mr. Chairman. Before I say anything else, I want to thank you personally, your staff, and the other members of your committee who worked so hard to support basic research during the recent Senate debate on the budget resolution.

The leadership you displayed and the willingness to set priorities in a time of very real fiscal constraints is very important to the Nation's efforts to regain economic competitiveness. We appreciate it very much.

In addition, let me also say that this hearing, is very timely, coming as it does during the week Congress has set aside for National Science Week. This hearing, along with 2,000 other events going on nationwide, provides us with a very unique opportunity to stop and focus on the impact that science and technology have on almost every facet of our life and also gets a message out of how important science is.

Mr. Chairman, the consistent support that you and this committee have provided the Foundation has made possible what I hope will become an expanded and long running activity of National Science Week and we thank you.

I have a prepared statement and, with your permission, I would like to submit it for the record.

Senator **Gorton**. Without objection, it will be so included.

Mr. **Bloch**. Thank you. First, I would like to introduce Dr. Roland Schmitt, who is the chairman of the National Science Board for some remarks.

Dr. **Schmitt**. Mr. Chairman, let me add my word of thanks to you and your committee also for your efforts on the budget. But my primary message this morning is that academic research and education is absolutely essential and vital to the Nation's economic and defense strength.

The international competition of the past decade has been waged and will, in fact, continue to be waged on technological grounds.

Our industries that have been surpassed, have been surpassed by more advanced technology. Those running neck and neck with the competition such as the semiconductor industry today will only stay that way if they keep pace with foreign technology. Those that are still ahead, such as the computer, aircraft engine, and plastics industry are ahead because their technology is ahead.

It is true that other factors play heavily in the competitive equation. It is true that we must have a level playing field, but on a level playing field, technology is the distinguishing factor. When the field is not level, technology is the offsetting factor.

If we are to win in the international competition, it won't be on the basis of cheaper labor or cheaper capital or a favorable exchange rate. It will be on the basis of technology.

So from an industrial perspective, by all means the Federal Government should strive to provide that level playing field. But just as importantly, it must make the investments in the basic resources that are needed by industry to win in that international competition.

Many of the requirements for success lie with actions that only industry can take, streamlining operations, for example, foresight in our investment, commitment to R&D, creativity in marketing and perhaps above all else, the ability to move quickly.

But industry also needs two things that it can't produce on its own: The scientific and engineering talent and the fundamental scientific and engineering knowledge that are the raw materials. It is only academic science and engineering, the science and engineering base, that can produce them.

Now, examples of the importance of the academic base to industry abound. One need look no further than to such university-spawned developments as silicon compilers, genetic engineering, artificial intelligence. Most of chemistry, materials science, solid state physics, biochemistry and computer science are so integral to industrial technology that the distinctions between basic and applied research are becoming even more blurred.

In many areas of engineering research, fundamental research issues, for example, in geometric modeling and analysis, in artificial vision, motion control and expert systems and the like are essential to the design of new products and processes.

Yet, despite the importance of the base to competitiveness, the strength of U.S. academic research and education base shows signs of wear. The symptoms abound in outdated research equipment, in obsolete and inadequate research facilities, in declines over the past two decades in the number of graduates receiving Ph.D.'s in key fields of science and engineering, in a concomitant increase in the number of foreign national Ph.D.'s, and the decline of science and engineering education across the board.

The agenda, not merely for the Federal Government—but for all of us, for industry, for universities, for the States, is large and it is growing. But it must be met, unless we are willing to cede our technological leadership to others.

That brings me to the National Science Foundation and its budget for fiscal year 1987. The NSF accounts for a very small portion of the Federal R&D budget, less than 3 percent. But in the context of international competitiveness, it is a critical, high leverage component of that Federal budget. It is the one component of that budget that is directly and entirely concerned not with the pursuit of Government missions but with the strength of the academic research and education.

It may be the smallest dollar component of the Federal R&D budget but from the perspective of competitiveness, it is in my view the most important. This is the context in which the fiscal year 1987 budget proposal ought to be judged.

I would like to thank you, Mr. Chairman, and all the members of the committee for the efforts that you have made over the past several years to secure a proper authorization for the Foundation. That has been important to us.

The change made in this year's bill to eliminate the restrictions on the Board's authority to delegate to the director authority to act on awards has had a very significant and beneficial effect on Board operations.

Since membership on the Board is a part-time occupation, we have been anxious to focus our attention on the points of greatest leverage, receiving programs and plans at an early stage in their formulation and thereby to help guide and shape the priorities of the Foundation.

We have taken advantage of the flexibility offered by the new authorization act to raise the minimum award level that requires Board review to those involving an annual commitment of $1.5 million or a total commitment of $6 million, which roughly accounts for inflation since the levels were last set some time ago.

We have also delegated authority for review of certain large but routinely occurring awards to the Director. These changes have enabled us to balance our efforts at project review with considerably more attention to the broader, long-term strategic issues that confront the Foundation.

We greatly appreciate the trust and the confidence in the Board and the Foundation that you demonstrated by making this change in the authorization act. We also appreciate the addition of the word "engineering" to the NSF Act. It acknowledges and reinforces our determination to ensure that NSF be attentive to the research and education needs of engineering as well as science.

Turning back to the budget for a moment, the President has proposed about an 8-percent real increase for the Foundation. He is also proposing real growth in Governmentwide support for basic research.

In the physical sciences and engineering, the increases are even larger. In light of the severe budget constraints that we are operating under, this increase reflects the administration's continued commitment to the strength of that base. In the context of the budget constraints, the increase is, indeed, substantial, Mr. Chairman, as you pointed out.

But in the context of the importance of the science and engineering base to the Nation's competitiveness, and in the context of the growing signs of strain in that base, the increase is also very, very essential.

This year's proposal puts a strong emphasis on four major areas—biotechnology, computational science and engineering, global geosciences, and broadening participation in science and engineering. Each of these areas significantly affects the health of the science and engineering base.

The first three of these strengthen the base at key points of leverage, where major new advances in knowledge are possible and where the economic effects on important industries will likely be substantial. The fourth will help build a base by helping to ensure a sufficient supply of high-quality scientists and engineers for our future work force.

Each of these emphases crosses disciplinary lines in many ways and involves many of the Foundation's individual programs. Such cross-disciplinary efforts are important because it is often at the intersection between old lines that the greatest promise lies.

Each will also foster still more cooperation between universities and industry and that, too, is part of the solution we are looking for. Both sides benefit when each gains the perspective, the experience and resources of the other.

Mr. Chairman, that concludes my prepared statement. Thank you.

Senator GORTON. Thank you. Mr. Bloch.

Mr. BLOCH. I would like to take a few minutes and summarize the reasons why it is important to support the President's budget request for the National Science Foundation.

You characterized it before as generous. I certainly agree with that, but let me also add a couple of adjectives to it: It is needed and it is indispensible.

There are three reasons why the Federal Government supports research and education in the sciences and engineering. They are, first of all, for its intrinsic intellectual value, second, because the Government needs the results and, third, for economic competitiveness.

The Foundation has long been dedicated, and stays dedicated to the first reason, intrinsic intellectual value. And the Congress has supported us in that view. The second goal is to create new knowledge that Government itself needs for security, for health, for agriculture and so forth. This is principally the concern of the mission agencies—but not exclusively.

I will concentrate my remarks this morning on the third goal, that of economic competitiveness. This is the area in which the nation is in most need. It is an area in which the NSF has much to offer. And it is a part of the rationale behind our major budget thrusts for this year as it was last year.

It is no secret that the world has become a much more competitive place in recent years. To illustrate this, I want you to consider a number of facts. We handed out some charts beforehand and I would like to go through these with you.

On chart No. 1 [following prepared statement] you see a story which is well known to all of us—that our trade balance is overwhelmingly negative and becoming more so. Even the advantage in high-technology products that we once took for granted is eroding, as you can see on the top of this particular chart. Even in the high-technology area, we are reaching a zero balance on our trade.

In both high- and low-technology products, the markets in which we must compete are increasingly international. The company that is first in the market with the most technically advanced product at the best price is the only one that will succeed.

Research provides the underlying base for the new products that we need to compete in high technology areas. Also, the process improvements that can raise productivity in low-technology manufacturing and service industry flows from technological innovations equally.

On chart No. 2 you see that over 44 percent of our productivity improvements over the last decade or so came from technological innovation. Research has been far more important and research results have been far more important than economies of scale, for example.

Many of NSF's programs support this process of innovation: Robotics, engineering research centers, biotechnology, materials research, and education of future scientists and engineers to name a few.

Research is the right way to enhance our international competitiveness and it is far preferable to reliance on trade barriers or other protectionist measures.

The science and engineering base consists of three elements: People, facilities, and equipment. Of the three, people are by far the most important. Facilities and equipment are relatively short leadtime items compared to education and attraction of people into science and engineering.

People come only through a long process of education. For a scientist or engineer, the process begins in junior high school and continues through undergraduate and graduate training, in all a dozen years or more. The length of the pipeline makes it imperative that we have a continuous flow of the most talented young students into the science and engineering programs.

This must be done through conscious policy. We cannot depend on market demand alone to ensure that we have the necessary numbers because the educational system cannot respond rapidly when the market changes. Therefore, as our society becomes more and more dependent on technology, we must be sure that we do three things: support basic research adequately, educate enough new scientists and engineers, and invest sufficiently in research facilities and in research equipment.

The United States has not invested in R&D in recent decades at a rate that sustained growth in a modern technological society requires. If you look at chart No. 3, you can see we have slipped in the 1970's: We are now beginning to increase that investment again. What has happened in the meantime is that other countries have accelerated their investments and are now spending at about the same rate as we do.

Furthermore, the proportion of our R&D that goes for defense has been both high and has been rising. If you look at chart No. 4, where we consider only civilian oriented R&D—which is the part that is most economically relevant—we find that our level of effort is behind that of West Germany and Japan.

An encouraging trend, however, is that our Federal expenditures for civilian R&D are increasingly for basic research as you can see on chart No. 5. The top curve shows increases during this administration that, include basic research as a proportion of the total civilian R&D research.

But what you also see on the second curve from the top on this chart No. 5, is that despite this tremendous increase, that if you consider basic research as a proportion of all Federal research, it is dropping and has been dropping for the last couple of years.

The reason for that is very simple: the military or defense R&D increase has been greater than any of the other ones; and the basic research expenditure in the DOD has not kept pace with that general increase.

There is no simple answer to the question. What is an optimum level of support for basic research? I don't pretend to know the answer. But I want you to consider a number of things.

When basic research is dropping as a proportion of total Federal support, as it is and as I just showed you, and we see increasing competition from our trading partners in basic research or in R&D expenditures, and we see shortages of scientists and engineers developing, and we all agree that facilities and instrumentation in universities are in a deplorable condition, then we can only conclude that we are underfunding basic research, especially basic research in universities.

Let me turn to the people problem. As our society becomes more dependent on technology, we will need more of our population educated in science and engineering. One consequence of underfunding basic research, however, is that we are attracting too few young people to these areas.

If you look at chart No. 6, 20 years ago the United States had far more scientists and engineers per capita than any of our competitors. And that is no longer the case. The gap is also closing. In fact, if you look at Japan as an example, in some of the disciplines important to economic competitiveness like electrical engineering, Japan is out producing us on an actual basis year after year.

If you turn to chart No. 7, you see that the proportion of our young people who are being attracted to scientific and engineering programs is declining. After steep increases during the 1960's and 1970's, it is declining now.

Even if you could continue to attract students at the same rate as in 1983, as I am going to show you on chart No. 8, we would have a cumulative short fall of science and engineering B.S. degreed people by the year 2000 of about 700,000 people. This is caused by the fact that the 22-year-age cohort is declining over the next decade, a fact that we can do very little about. So we have to use other schemes and other means of attracting people to science and engineering.

Increasingly we are dependent on foreign nationals for new Ph.D.'s in engineering and in mathematics and physics, the most critical disciplines of a technological society as shown on chart No. 9. While we benefit from this trend, since many of these students stay here and join our work force, our overdependence on foreign citizens as a resource that vital should give us cause for concern.

We have no control over that resource. It can stop at any minute, as happened a few years ago with respect to Iran, as an example.

Federal investment in academic research facilities has declined almost 95 percent since 1965. The programs that once strengthened our university infrastructure no longer exist. NSF's investment in research and instrumentation is up too, as you can see on your last chart, No. 10. And it is increasing also in the 1987 budget, but I need to tell you that this is still below the funding requirements that exists out in the universities.

We probably should be at the 22 percent level or 20 percent level of our total budget when it comes to equipment and instrumentation. We are running at about 16, 17 percent because that is all that we can afford.

Mr. Chairman, the strongest case that I can make for the support of the President's budget request for the National Science

Foundation is that we must begin to do something about the trends I have just outlined.

Our increase is 13 percent over that of 1986, if you include the Gramm-Rudman reduction that we took in March of this year or, as the chairman said, 8 percent before Gramm-Rudman. It is encouraging that even in a time of great austerity in Federal funding, the administration and Congress recognizes the need for an increase in our budget.

The proposed increase will go where it will do the most good—to support basic research and education. We feel this is critical to advancing our economic competitiveness. I would want to emphasize that each of the areas that we are addressing—biotechnology, computational science and engineering, global geosciences, broadened participation in science and engineering—are areas that are of extreme importance and that have a direct impact on our economic problems and, hopefully, on our economic solutions.

Mr. Chairman, I would like to leave you with an overriding thought. Investment in science and engineering research and education has been the source of much of our economic progress in the last four decades. It continues to be the best single way that we can provide the jobs that we must have in decades to come.

I urge you, and I know I don't have to urge you because you have spoken to this point yourself, to ensure that we have the resources necessary to meet this particular challenge. I thank you.

Senator GORTON. Thank you, Mr. Bloch. This morning the Office of Science and Technology Policy released the report of its White House Science Council on the health of U.S. colleges and universities. At the moment, there is a hearing on this report taking place in the House.

Although optimistically entitled "A Renewed Partnership," the report really presents a fairly grave picture of the health of our universities. Can you comment on the report and give us your own assessment of the health of our universities in this field?

Mr. BLOCH. I will be glad to do that. We have, obviously, worked with the White House Science Council in formulating that report. In general, we are in agreement with it.

The report recommends that we double the financial support over the next 5 years as a minimum to keep pace with overall national investment in R&D. That was exactly the point I tried to make before.

Our basic research component is dropping as a percentage of the total R&D that the Federal Government supports. That should give us cause for concern. The report focuses directly on that issue and doubles the financial support as a goal over the next 5 years. I support that recommendation.

It also focuses on university based interdisciplinary research and technology centers as a way of enhancing the research activities of the universities and the model for that is the Engineering Research Centers Program of the National Science Foundation. It applies across the board, not only to engineering. It certainly applies to many of the sciences themselves.

The report also states that the Federal Government should bear the full share of the research costs that a university incurs when it enters into a grant or a contract. We support that.

It focuses very heavily on the need for putting the equipment situation and the facility situation on a more business like basis by establishing depreciation as an allowable charge. These funds would be set aside as a source for new investments as old equipment wears out or becomes obsolete.

It focuses on the facility problem and echoes the point I made before, that the Federal Government has stepped away from facility funding for 10 or 15 years. I should tell you my priorities: it is support people, equipment and facilities in that particular order.

Even with the best facilities, if you don't have the people, you can't do very good research. And if you have very good people and good facilities and you don't have the right equipment, research results lag.

The report also suggests some positive steps to support indirect costs and also to limit indirect costs, which as you know is a very controversial subject at this point in time. The Foundation has taken the position that we support limiting indirect administrative cost but couple it with a fairer recovery system on equipment and facilities. I think in the end that would help us all, the universities as well as the Federal Government. The report talks to a great extent about lessening the administrative burden of grants and contracts. We are all in favor of that. In fact, we have an experiment starting now in the State of Florida where the Federal Government, together with the State government and the universities, both private and public universities, are looking to see how we can reduce the administrative burden that the Federal Government puts on the university principal investigator and therefore, also reduce the administrative cost.

I want to say on that point that the Federal Government is not the only culprit. The States are responsible for it and so to are the universities. All in all, the report is a very positive one. We support it, certainly. You might have some quibbles on a few details and on priorities, as I mentioned, but that doesn't detract from the important points of report.

Senator GORTON. In your statement you mentioned in passing the effect of Gramm-Rudman, which did, during the course of this year, require you to sequester something over $65 million.

How did you carry out that reduction and what effect did it have on your programs?

Mr. BLOCH. As you said, it was a fairly large sum that we had to remove from our plan in March of this year. We didn't take the viewpoint that we would cut everything by 4.3 percent. In fact, we went back to our appropriations committee and got dispensation from that in certain areas.

We protected mathematics. Why did we protect mathematics? Because we built up mathematics very carefully and very slowly over the last couple of years. To turn around and take 4.3 percent away from it didn't seem reasonable.

We protected the ocean drilling program. We protected the minority and women programs that we have carefully constructed in order to attract more women and minorities into the science and engineering area. We didn't take anything away from that.

We protected the number of graduate fellowships and the stipend level. We did reduce the administrative allowance to universities.

We felt that reducing student support would be the wrong signal at a time when the attraction of young people to careers in science and engineering is a problem.

We did all of these things. Then we gave our program officers the authority to reopen all contracts or grants that had been entered into from the beginning of the year so that we would not unduly affect new awards.

Last but not least—we urged universities, as we asked them to make the reductions in particular grants, to protect the people, especially undergraduate students, graduate students, research fellows and to protect instrumentation because of the problems that I cited earlier and take the reductions out of administrative expenses. How successful we will be with that, we will see.

Senator GORTON. You wouldn't be able to handle so smoothly an analogous but much larger sequester in 1987 if it should take place, would you?

Mr. BLOCH. Let me say, first of all, this was not as smooth as it sounds because a lot of thought has gone into it and, obviously, there are a lot of problems that we gave to somebody else with this reduction. But, you are absolutely right, if a much larger reduction would occur in 1987, then we would have to look at some completely different priorities.

We would have to come to grips with the question of what we can no longer afford in terms of institutions or in terms of activities. We would also have to look at the closing of facilities.

We also would have to review some of our established policies, for instance supporting salaries for principal investigators. We indicated in the notice that we put out with the 1986 reduction, that that would have to be looked at. Can we afford to support the principal investigator's academic salary or summer salaries to the extent that we are today? That is questionable. So we would have to look at very basic policies and strategies in order to absorb a much larger reduction compared to 1986.

Senator GORTON. The Foundation's Antarctic program has important international implications. Has it been affected by the New Zealand Government's ban on port calls by nuclear powered vessels?

Mr. BLOCH. It hasn't been affected yet, but obviously that is an area about which we are very concerned.

In the end, we have to look at logistic alternatives. Let me point out that alternatives are not very palatable because they require a lengthening of the logistical pipeline, an increase in costs, and the rebuilding or building of new facilities.

Senator GORTON. Would that take place if legislation which is apparently pending in New Zealand expanded the policy to all kinds of craft?

Mr. BLOCH. I don't know exactly how that would work. Right now it is the policy of both the United States and New Zealand Governments to insulate cooperative activities. This happens to be a cooperative activity because New Zealand is very active in Antarctica also.

We hope that cooperative activities of this sort will be sheltered from the legislation, but there is no guarantee.

Senator GORTON. Senator Goldwater especially asked me to ask the question as to why the Foundation is asking for only a 1 percent increase in astronomy in fiscal year 1987 as compared with much larger increases for other scientific disciplines?

Mr. BLOCH. Well, let me say two things. Obviously any budget request that is submitted makes a lot of compromises and has to establish priorities among disciplines. We submitted what I call a realistic budget. If we had come in with a 20 percent or 25 percent increase, we would have been laughed out of the room, thus we had to make some very tough decisions.

Not all disciplines, and not all divisions, and not all directorates got the same increase. I believe that we did the best we could do with regard to astronomy. I just felt that other areas were more important at this point in time. I mentioned mathematics before as one which received the biggest percent increase in the Foundation.

Let me point out that over the last 3 years, astronomy has received some increases. We cannot expect all areas to get the same increase every year. That is no reflection on the work that is going on in astronomy.

Senator GORTON. Senator Goldwater has several other questions on that subject which he asked to be submitted in writing, as well as a number of additional ones on my part. But now I would like to ask one or two questions of Dr. Schmitt.

Both you and Mr. Bloch have stressed the importance of basic research and its link to economic competitiveness. Are you satisfied with the total Federal investment in basic research?

Dr. SCHMITT. No, not at all. I think Mr. Bloch in his testimony and other documents, speeches he has given and I have given, has pointed out that there is a set of very, very severe problems in the academic research community in the United States today that involve facilities. They involve empty faculty positions. They involve equipment. They involve students.

The number of Ph.D.'s in engineering, for example, has actually gone down at the same time that the fraction of Ph.D.'s given to foreign nationals has gone up. So if you look at the Ph.D.'s in engineering and science given to U.S. nationals, it has dropped dramatically. I think it is a very, very ominous sign.

Now, the fact that Mr. Bloch pointed out earlier, mainly that the fraction of Federal R&D budgets going to basic research is going down is also an ominous thing because it is the basic research that is essentially the resource producing part of the whole equation.

It is the part that produces the students, the human resources, the fundamental knowledge on which all else depends. So when national expenditures for applied research and development are increasing, that is a signal that we need more input of basic research resources.

So I think that there are many, many signals that show that the situation is not improving significantly and is one that we should all be concerned about.

It is clear that the budgets of the National Science Foundation alone are not enough to solve the problems, so I think it has to be solved by additional resources from some of the mission agencies being targeted at the basic academic research also.

Senator GORTON. One other question for you. What, Dr. Schmitt, is your reaction to the recommendations of the Oberlin conference that more small colleges be represented on the National Science Board?

Dr. SCHMITT. I react very favorably to that. I think it would be very helpful to have voices from that community on the National Science Board.

Senator GORTON. You will have that opportunity soon?

Dr. SCHMITT. We only recommend, we do not choose, as you know.

Senator GORTON. I have other questions I will submit to you in writing as well. For now I will turn to Senator Riegle.

Senator RIEGLE. Thank you, Mr. Chairman. Mr. Bloch, I would like you to be as blunt as you can be and as straightforward as you can be in telling me how you think the United States is doing these days in terms of producing top level graduate, postgraduate doctoral people in the most technical scientific fields.

And I am thinking now of physics and advanced mathematics, and so forth. How are we stacking up in terms of the number of people coming through our American institutions and the numbers that are needed?

Mr. BLOCH. Well, as you know, Senator, I am always blunt on any subject, especially on this one. I think we have a big problem.

Senator RIEGLE. A big problem. Well, describe it for me.

Mr. BLOCH. The problem is the following: we are not attracting enough people to the Ph.D. track. Let me cite a case. If you look at the number of Ph.D.'s as a percent of B.S. production in a given year, it is falling.

Senator RIEGLE. So the number of people going on for doctoral degrees is falling?

Mr. BLOCH. There are fewer than before. That is Point No. 1. Point No. 2—as I mentioned in my statement, we are depending very heavily on foreign students to fill the Ph.D. track.

Senator RIEGLE. What would be the percentage of foreign students, roughly, in the advanced scientific disciplines?

Mr. BLOCH. It depends on the discipline. In engineering it is 55 to 60 percent.

Senator RIEGLE. 55 to 60 percent of the doctoral engineering candidates are now coming from foreign countries?

Mr. BLOCH. Right. In some of the other areas, it is less, but even in mathematics it is about 40 percent.

Senator RIEGLE. 40 percent in mathematics? How about physics?

Mr. BLOCH. Physics, it is probably less than that, maybe 25, 30 percent.

Senator RIEGLE. So are the trend lines rising here?

Mr. BLOCH. That was my next point. That is the disconcerting part, that the trend line is rising. Let me give you another data point. If you look at the number of Ph.D. computer scientists that we are producing on a yearly basis, it is about 200.

Senator RIEGLE. Two hundred in the entire country in computer sciences with Ph.D.'s?

Mr. BLOCH. That includes foreign students.

Senator RIEGLE. 200 for the whole country. How many do we need, would you say?

Mr. **Bloch**. Well, you never know how many you need, but you know you need more than 200. And, in fact, there are reports around that assert that 2,000 is probably the right number. I don't know if that is true but I would say that is closer to the truth than 200.

Senator **Riegle**. If we need 2,000 and we are getting 200, we are getting 10 percent of what we need, and we are falling short by 90 percent in terms of the actual needs here.

Mr. **Bloch**. That's correct. Now, you can also ask why that is. There are a number of reasons. It is not just one single cause.

First, is the attraction of industry. If you have a B.S. or M.S. degree in computer science, you can demand a very high price in the marketplace.

Senator **Riegle**. What would be those relative starting salaries now, just a range?

Mr. **Bloch**. This year I would say for a starting B.S. degree or M.S. degree is something between $30,000 and $35,000.

Senator **Riegle**. For the Master's degree?

Mr. **Bloch**. For the Master's degree, somewhere between $35 and $37,000. The point is that going for a Ph.D. degree, which is a long drawn-out process, you are essentially facing an economic loss over what you could experience if you were to join industry.

Senator **Riegle**. We obviously have got to find a way to change that or we are going to fall behind. Even by relying on foreign students to fill an increasing slice of our doctoral needs, we are still going to fall behind as a nation if we are not cranking out these very needed specialties.

What thoughts do you have as to how we can create a greater sense of alarm in the country about this in a constructive sense so that we start to focus on this problem and attract answers to it?

Mr. **Bloch**. Let me say two things first and then I will come back to your question. The need is really in two areas. First, industry needs more Ph.D. degreed people in order to do the complex tasks that it must accomplish in the future, compared to what it does today and did in the past.

And, second, we obviously need faculty. There are many faculty openings today, especially in engineering and computer sciences. Unless we fill these faculty openings, we can't educate our undergraduates.

Senator **Riegle**. So we have problems in both areas. We are having difficulty attracting the teaching talent as well as the student body?

Mr. **Bloch**. Yes; now, to answer your question, what must we do to attract more people to the Ph.D. track—first, I think we have to make sure that we make it easy for people to follow that particular track through stipends, graduate fellowships, and so forth.

We are doing quite a bit about that but probably not enough. The Presidential Young Investigator Program addresses a slightly different area, but a highly related one; namely, to attract and keep faculty in university careers.

The third thing which we need to do is to narrow the pay differential between a university salary and an industry salary—which has been narrowing, I must say, over the past 3 or 4 years, especially in those areas where there are shortages in universities. We must continue that. We will never close the gap completely and I don't think it is necessary, but we have to bring the two closer together.

Last but not least, the whole ambiance and the environment in the university has to improve. My example is instrumentation. If you find better instrumentation in an industrial laboratory then you find in the university, you are going to go to the industrial laboratory to do your research and that is the case in many areas. We need to reverse that situation.

Senator **Riegle**. In the same spirit of bluntness, I want to pursue this subject with you. We have a shortage. We have institutional constraints that are preventing us from being able to break out of this shortage problem. The trend lines are running in the wrong directions.

I don't serve on the Armed Services Committee but from what I gather, the acceleration of effort with SDI, for example, is a very expensive proposition. One manifestation is that we now have a Space Program in the Defense Department that is costing $15 billion a year, twice as big as the NASA Program, much of it driven by SDI.

I am reading more and more stories about the fact that there is enough money out there to do SDI research, that it is beginning to preempt other fields because of the power of that money and the need for researchers to be able to function, that it is drawing people in that direction and away from other activities that they might be in.

If that is so, that is a concern to me. It raises the question that if we have a shortage any way, do we want to take and tilt what is available in one direction to the exclusion of other competing directions?

I am concerned about that. Do you detect any of that going on?

Mr. **Bloch**. It would be much too early to detect it. Let me say something a little bit different about that. If SDI, to take your example, would invest in open basic research as much as they should, then maybe that would help the problem.

My concern about SDI is that I have not seen that they are investing as much as they should in open basic research; areas like mathematics, and many materials research areas, which really have a bearing not just on SDI but on the whole basic research enterprise and the civilian sector as well.

If SDI would take a portion of the R&D funds and put it into basic research, I think that might help rather than hurt. Equally serious is the potential drawing of people into that area away from the civilian sector. I think it is too early to judge that case. Maybe Dr. Schmitt would want to comment on that.

Senator **Riegle**. Dr. Schmitt, do you see that happening?

Dr. **Schmitt**. I think it is early to really say that but it is clear that as the technical effort for enterprises like SDI goes up, that the manpower has to come from somewhere. That is the point on which I agree totally with Mr. Bloch; namely, for large programs that are clearly going to require large, additional influx of manpower in the future, attention must be paid to the sources of that manpower. And the sources reside primarily in the basic academic research areas.

So I think that it ought to become kind of a part of the whole climate that when we are building up large mission oriented programs, we should simultaneously pay attention to the basic research and manpower training requirements.

If you go back after World War II, that is exactly what happened within the mission agencies and especially DOD. And it resulted in a flowering of U.S. science. So if we just recall the lessons we learned after World War II and apply them today, I think that would be a very important step.

Senator RIEGLE. Yesterday in the Banking Committee, Commerce Secretary Baldrige was there. We were talking about the trade deficit. The United States, as you know, is running a trade deficit of about $150 billion a year. It far exceeds anything we have ever experienced before and it has been so severe so long that we have become a debtor Nation for the first time since 1917. Within 6 months we will be the No. 1 debtor Nation in the world, just in terms of our international financial balance sheet.

We are going deeper and deeper in the hole. And there is no prospect of this turning any time soon, despite the fall of the dollar and so forth. The New York Federal Reserve Board is estimating that by 1990 we are going to owe the rest of the world as a net-debtor nation somewhere between $500 billion and $1 trillion, which is an astronomical change and an adverse circumstance for us financially.

A lot of people think the answer for turning that around is technological breakthroughs, that we are going to have to become more productive. We have had very anemic productivity growth. All of that implies that you have got to have this base of scientific effort and research and breakthroughs with a lot of very talented people working very hard and moving us ahead faster than other nations are going—faster than Japan and other nations that are investing in high technology and training and so forth.

Then we find that Japan is turning out twice the number of engineers each year on a per capita basis as we are, so that they are moving ahead at a faster rate and widening the gap. In a sense, we are finding ourselves in a more adverse position.

It seems to me that if we are going to restore our international economic competitive situation, we have got to have a massive breakthrough in terms of fundamentally changing these trend lines and producing many, many more people in our society who go into these specialties. If we have to pay more to get the professors away from business and into classrooms so that we can expand the base of trained scientific people, it seems to me we have to do it.

Now, have you set off the alarm bells in the White House? Have you set it off at the cabinet level as much as you can? How do we alert people to the fact that our future, our economic future and our job future and our living standard future, depends upon producing enough of these highest level talents so that we can invent our way forward at a fast enough rate? Otherwise, it seems to me, we are going to face a bleak future.

What is happening there? Are you able to arouse any interest and concern at the highest levels within the administration or not?

Mr. BLOCH. I think the budget request of the President attests to that fact. The fact that we have a 13-percent increase in the NSF budget, I think, is testimony that that message is understood.

Senator RIEGLE. Wait a second. If you need 2,000 advanced computer people, as you were describing them, and we are producing 200, is this a budget that closes that gap even in 10 years?

Mr. BLOCH. No, this budget doesn't close that gap and you can't expect that the gap, will get closed in 1 year. But if we can keep an eye on that, take a look at the total R&D budget, and do some reallocations between development and basic research. I gave the example of SDI, but there are many others.

If we did those things, I think probably we could address this problem better than we are addressing it today. I think you made a very eloquent plea for the National Science Foundation's budget request.

Senator RIEGLE. I hope I am because I mean to. I think we are endangering our future. I think right now what we are doing is we are living off our past accomplishments. It is like depleting a bank account. We are using up investments that we have made in the past.

We talk about infrastructure like highways and bridges and water systems, and we have had problems there too, but if our human infrastructure and our scientific people in these advanced areas are not there in sufficient numbers and if we are not enriching that whole activity across this country with enough money and talent, there is no way that we are going to be able to maintain our position in the international competitive race that we are in. We are not maintaining it. We are sliding backward.

There is a lot of comment that glosses over that fact and makes it sound as if things are better than they are. But the bottom line, if you look at the economic numbers and the job numbers, is that we are seeing a terrific erosion in U.S. strength vis-a-vis the rest of the world and the world trading system.

So it seems to me that we have to find a way to get this message out there and out of this room and out over the country as much as we can. I think the American people are willing to make the investments needed to turn out enough high level scientific and research people to help us maintain the kind of lead internationally that we have to have.

Otherwise, our children are increasingly going to have less and less. They are going to be consigned to more menial jobs, whether it is flipping hamburgers at McDonalds for a lifetime. Not that that doesn't have to be done by somebody, but we can't all do that if we are going to have the kind of living standard that we aspire to.

If we are going to project U.S. values and strength around the world, we are going to have to have an entirely different kind of future economic strength than I think we are headed for now. I am very concerned about it. I am afraid that the debate isn't focused in this area. I think we are off chasing rabbits in other directions and we are not concentrating on the fundamentals that really relate to our future.

I think my time is probably up here. I have a whole series of questions but I don't want to trespass on Senator Rockefeller's time.

Senator Gorton. Senator Rockefeller.

Senator Rockefeller. Mr. Bloch, listening to Senator Riegle, it makes me think that it is not just a matter of money. I am, frankly, very pleased by this budget proposal. I have some questions about it. I am going to ask at least one or two of them.

But it may be that the problem is more than just a matter of money. You can get down to the whole SDI question, which is very troublesome to me, and DOD moving in on NASA, which also has troubled me for a long time.

But other factors also seem important. For example, we have no national consensus here. You can get a national consensus, when this country is in danger from some external force from a security point of view and, therefore, we have to prepare for that. The trade imbalance is more obscure; debtor nation is certainly is true but it barely seems credible. It certainly is recent and doesn't excite a great deal of response.

We Senate Democrats have a group that has been working on the whole question of competitiveness. One of the criticisms that has been made is that it is not just a matter of the amount of money that is being spent on math and science. How early it is being spent is also important. In other words, I guess you can hypothesize that it is going to be very tough to get your Ph.D. production higher until the students get into math and science and physics at a very early age. The Ph.D. is at the end of the process. You have to motivate people early on in the process. One other point that was brought up to us is there is a certain diminution of the will to compete on the part of American business. Your charts on nondefense R&D show the West Germans and the Japanese way ahead of us and constantly ahead of us.

People say: Well, it is hard to compete with the Japanese and the Koreans because they have very low wages, particularly the Koreans. But you can't make that argument with the West Germans. It is a high wage country, with a deep commitment to education, and a deep instinct for technology and innovation.

I am interested in this business of the mood of the country, the soul of the country with respect to science, technology, aggressiveness for competition, and whether, you have seen any diminution in these areas.

There are two ways of looking at that. One is that in the 1950's and 1960's, certainly the 1960's and most of the 1970's, we were uncontested. That does not necessarily say we were hungry. It might simply say we were wealthier and that we had innate educational advantages.

The other possibility is that we are not aggressive enough. If 55 percent of Ph.D.'s now in engineering are foreign, that doesn't trouble me at all. We are a nation of foreigners. And that is provided they at least to some significant degree stay in this country.

But if that reflects a lack of hunger on the part of our culture, our education, our mind set, to press ourselves forward, to be lean, to be hungry for self-improvement, that I think would be truly troublesome.

Budgets can stimulate that to a certain degree, particularly where budgets are inserted into the beginnings stages of education. But I wonder if it is a deeper syndrome than that. I am asking you a very hard, judgmental type of thing, can you respond to that?

Mr. Bloch. I will be glad to say a few things about it. And probably Dr. Schmitt would like to comment also. I came from industry roughly 2 years ago to this particular job. I didn't see, at least in the industry that I was familiar with—which is computers and semiconductors—a diminishing of the competitive drive or lack of urgency. I didn't see that there. So I don't think that is a general situation.

I mentioned before that the foreign percentage of Ph.D. graduates doesn't bother me either. I am the person to complain about that.

What bothers me is that our dependence on foreign students it has gotten to a very high level and we have no control over it. The flow of people can dry up on us tomorrow. That is what bothers me. Right now, most of the people stay here, but that can change overnight. And then where are we? That is a concern I have.

Now, why aren't more people following the Ph.D. track or more people getting attracted to science and engineering? Well, I suspect a lot of it has to do with the preparation in elementary schools and preparation in high schools.

After all, the natural sciences and engineering are very difficult subjects in college. And to get trained in mathematics only after you enter college is late and makes the study difficult. So I think we have a pipeline problem, or preparation problem, that we need to address.

The Foundation has put a lot of emphasis on funding pre-college education. We continue to do that. However, we can't do everything in that area. We are a small agency. As a whole, funding for pre-college education rests in the states and localities. But we can stimulate it and we can point the way. We can show by example what can be done.

Then, last but not least, there is a wide gap that exists between salaries in universities and in industry. Maybe Dr. Schmitt would like to comment.

Dr. Schmitt. I would just add two comments. One, as I indicated in my opening statement, U.S. industry really does still have a preeminent place in certain areas—computers, aircraft engines, high performance plastics and the like—all based on high technology and the leadership that we have established. So we still, in fact, are quite capable of doing that.

And I would hope in the areas of biotechnology, we will turn in a similar performance in the future. So I don't think there is any diminution of the competitive drive. I do agree with your observations, though, that in an earlier era, we had much less intense competition from abroad and probably fell into some habits of execution that are not appropriate for today's competitive environment.

So my interpretation of what has happened is that the drive is still there. The interest in being competitive is still there. The U.S. industry is having to relearn some of the successful ways of doing that because of the harsher climate we are in today.

Two-thirds or three-quarters of the CEO's of Japanese corporations are either trained in the sciences or in engineering. Now that is a cultural statement about education, about mission, about the length of time that it takes for a return on an investment. And it also has to do with what young people pattern themselves to be.

Conversely, in this country I think about three-quarters or approximately that of the CEO's of our major corporations are either lawyers, accountants or PR types. And that is all fine but that sends a very different message, I think. That may be what I am trying to get at.

There appears to be a cultural desire to see a quick return, which is the so-called quarterly report syndrome. That is understandable in a world where we are preeminent and very dangerous in a world where we no longer are.

I understand that 44 percent of productivity improvements come from technological innovation. I look down there at education and see 12 percent and I get very nervous because to get the level of competitiveness Senator Riegle is talking about will take a major investment in education. You are doing some of it, I hope you are doing it at a low enough level, that is, in the earlier years. But the education aspect remains central. I don't think you turn the country around except through two ways. One is fear. In other words, we did it in 1957 with Sputnik. That was fear. That was silly fear. Who cares in one sense whether Sputnik went up?

That wasn't a threat to the Nation but we perceived it as much and math and science exploded. Now we have something we should really be afraid of, which is this $150 billion trade deficit but much more important than that, a very real diminution of national capacity to compete. I suggest a diminution in the will to compete, the instinct to off-shore a source rather than compete. Well, OK, so we invented it but we can't produce it as cheaply so we will produce it off-shore.

Is IBM American or is IBM international? Is Caterpillar American or is Caterpillar international?

The education thing, it seems to me, other than fear, is the only way to really get at these problems. That is not a question. I guess that is a statement.

I look at the 12 percent of U.S. productivity increases being laid on education. And I just worry that somehow that is misleading. It may be true statistically, but it seems to me misleading. Do you want to comment on that?

Mr. **Bloch**. I hope you don't misinterpret chart No. 2 from which you just quoted. This doesn't diminish the need for education at all. It focuses on a slightly different problem.

If you analyze what causes productivity to increase in a direct way, assuming you have the right labor force in place, assuming you have equipment in place and so forth, and now you make incremental improvements on that investment or incremental increases, then essentially 12 percent is allocated to education.

All of these things—scale economics, et cetera—are very important. If you only produce one widget, you can't have the same costs of somebody who produces a million, but it only allows 16 percent in this particular analysis. That doesn't diminish the need for scale economics. It just says technological innovation was more of a driving force than scale economics on a relative basis.

Senator ROCKEFELLER Mr. Chairman, I will ask one more question. And Senator Goldwater asked the same question. I also—and for a parochial reason, not just a national reason—am concerned about the 1 percent increase in the astronomy budget as opposed to the overall 8 percent increase.

Again I am very pleased with the budget. I think it is excellent. I am very pleased that the President has submitted it at this level.

You know in West Virginia that we have the Greenbank Radio Observatory and we have relatively few efforts of that sort. If you go through your charts on different levels of funding to educational institutions, first R&D to universities and colleges, then the same thing on a per capita basis, the smaller states, and obviously I would look at West Virginia, tend to be blurred into the bottom line of the charts so that they are barely visible.

I understand why California and New York and Massachusetts get the majority because they have a very large educational infrastructure. They have a very large degree of excellence in place and excellence tends to breed more of it. But that does raise the geographic distribution question.

There are amazing things that can happen from smaller places, if they are given the chance. If in the Gramm-Rudman philosophy, if in the scarcity philosophy we only play to our strength, then by definition the long lines are going to get longer and the shorter lines are going to get shorter.

I am not sure that is wise. It certainly is unfair. If it is unfair but wise, then it is harder for me to argue against. If it is both unfair and unwise, that is something I want to look at.

But with specificity to the astronomy budget and its implications for the Greenbank Observatory, the VLBA radio telescope is a matter of concern to me. I want to see that place do very, very well. And I simply want that to be noted.

Mr. BLOCH. Can I comment on West Virginia on the chart you just mentioned? That is a State where we have tried to do something very special; namely, to bring it up to a higher level to compete in the scientific and engineering areas. So we are addressing that problem.

Senator ROCKEFELLER. Thank you, Mr. Chairman.

Senator GORTON. Senator Gore.

Senator GORE. Thank you very much, Mr. Chairman. Mr. Bloch, Dr. Schmitt, I would like to add my welcome to the others you have heard.

I count myself as a strong supporter of NSF.

I have a number of specific questions that I would like to ask briefly. First of all, I am extremely concerned about the greenhouse effect. In the House I chaired a number of hearings on this problem.

And I am wondering what priority NSF is assigning to research into the greenhouse effect. I know that you support the National Center for Atmospheric Research at Boulder and they are doing excellent work on both CO_2 and the trace gases, but is that the only NSF involvement on this problem?

Mr. Bloch. First of all, you cited the very source in Boulder, which is largely supported to by NSF. And we are spending about $45 million a year at NCAR. We are doing a lot of work, not just what you just mentioned, but in a broader sense.

The greenhouse effect, as you mentioned, results from chemicals in the atmosphere, increasing and decreasing trace chemicals of extreme importance. In addition to that, NSF also has grants and projects in place independent of NCAR. And I can't quote you the number right now but we would submit that for the record.

Senator Gore. If you could submit that for the record, I would appreciate it. I have no doubt whatsoever in my own mind that the greenhouse effect will soon be recognized as the environmental problem for the remainder of this century and on into the next century.

And we not only as a country but we as a civilization have been very slow to recognize how serious it is and how urgent is the task of better understanding it and mobilizing whatever reasonable response might be feasible. That might involve retrofitting power stations on a massive global basis in order to build confidence that might stand us in good stead when and if we tackle the problem of fossil fuel consumption patterns.

In any event, I look forward to your responses.

[The following information was subsequently received for the record:]

Greenhouse Effect

Global warming which results from increased concentrations of carbon dioxide and trace gases in the atmosphere is often referred to as "the greenhouse effect". The study of carbon and other elements as they cycle through the atmosphere, oceans, and solid earth is fundamental to understanding climate and climate change.

During FY 1986, the National Center for Atmosphere Research (NCAR) will be conducting research on the greenhouse effect of carbon dioxide and other chemicals in the atmosphere at an estimated level of effort of $1.6 million. Of this, NSF is providing $1.1 million, and other agencies (primarily the Department of Energy), $0.5 million. These funds support field and laboratory analyses, computer modeling and other services, and research salaries.

In addition to the ongoing research effort at NCAR, NSF grant programs in Geosciences and Biological, Behavioral and Social Sciences support the following areas of climate research related to carbon dioxide and trace gases: carbon cycle measurements, carbon dioxide and climate modeling, vegetation responses to carbon dioxide and climate, and other effects (e.g., sea level changes).

The total NSF support for these research grant activities was $4.9 million in FY 1983, $5.3 million in FY 1984, and $5.2 million in FY 1985. It is anticipated that the FY 1986 level of support will be about $5 million.

In the FY 1987 NSF Budget Request, the Global Geosciences thrust ($18.2M) includes several programs aimed at understanding climate and chemical cycles in the global environment. The Tropical Ocean/Global Atmosphere (TOGA) Program will examine the coupling of physical processes between the atmosphere and oceans. The World Ocean Circulation Experiment (WOCE) will include study of the mechanisms for transfer of heat and chemicals within the oceans. Aspects of the production, transformation and disposition of chemical constituents, and their interaction with living organisms, will be studied in the Global Tropospheric Chemistry, Global Ocean Flux, and Global Ecosystem Dynamics programs.

Senator Gore. On a related subject, do you have any new information about the so-called hole in the ozone recently discovered above Antarctica?

Mr. Bloch. No, I don't have any new information. Again, we would be glad, however, to submit an update for the record.

Senator GORE. I appreciate that. May I assume that this is going to be your top priority in the Antarctica research programs this coming year?

Mr. BLOCH. I don't know if you can assume that. The program that we have in Antarctica is wide-ranging. Where it stands in the priority list I can't tell you right now. But, again, we will be glad to submit that to you for the record.

[The following information was subsequently received for the record:]

ANTARCTIC OZONE HOLE

The ozone hole in the atmosphere that has appeared in the Antarctic Spring over that continent for the last several years is being studied this year as a major priority. This involves British scientists, Japanese scientists, and those of other nations, as well as U.S. scientists. The international Chemical Manufacturers Association is also involved and is providing some of the research support. The U.S. part of the project will be supported by the National Aeronautics and Space Administration, the National Science Foundation, and the National Oceanic and Atmospheric Administration as a concerted special effort.

Current plans call for NASA, NSF and NOAA to support research and for NSF/Antarctic Programs to provide antarctic logistics and coordination. The project includes both examination of satellite data and ground-based science such as the launching of balloon-borne ozone sondes from several antarctic stations. The aim is to collect data that will provide an explanation of this seasonal phenomenon for which several hypotheses exist. A sizeable field team will be assembled and taken on special flights to Antarctica in August, 1986. It will then be in position to make key observations at the ozone depletion maximum in September and October.

This is one of a number of high priority projects in the polar regions that are concerned with atmospheric and climatic change.

Senator GORE. I will look forward to your response in the record. And I will only add my only sense that it should be at the top priority because the implications are quite enormous. And we need to quickly establish whether it is a phenomenon that has recently appeared or one that has been going on for millions or billions of years.

Coupled with the growing haze above the Arctic region, the two phenomena together could have very disturbing implications, and we need to increase our understanding of them very quickly.

Moving to another subject briefly, a more mundane concern, the Engineering Research Center program was established to benefit American industry, at least in large part.

Do you have any information on how many foreign companies now participate in the 11 NSF supported Engineering Research Centers?

Mr. BLOCH. Whenever I visit a center, I ask that question. So far, from what I can tell, there is no participation by a foreign country.

Senator GORE. In any of the 11 centers?

Mr. BLOCH. First, only six centers really have been established. The other five have only just been announced.

The ones that have been in existence for about 9 months are the only ones that one can really talk about. It is a subject that is a difficult one to address. It has to do with how much we would get out of it. It also has to do with reciprocal access to the capabilities of the other country. We need to judge this on a case-by-case basis. Let me assure you, it is an area that concerns me greatly and that I will follow closely.

Senator GORE. I understand. I don't want you to misinterpret the question as an expression of jingoism. I feel very strongly that the support by the American people for basic scientific research will grow if the American people clearly perceive the clear connection between our ability to compete in the global economy and our Nation's willingness to invest in basic research.

And I just think that we need to recalibrate our attitude on American participation in these programs a little bit, so that we don't get into the kind of situation we have had at Mass General Hospital or a number of other examples I could cite where public funds are leveraged by foreign competitors to American companies to get basic research of near-term commercial value that worsens the trade deficit.

But let me move on, if I can, because I don't have much time here.

The new earthquake engineering centers, how many will NSF establish this year?

Mr. BLOCH. Right now our program calls for one.

Senator GORE. Where?

Mr. BLOCH. I can't tell you that.

Senator GORE. If you could supply that for the record, I would appreciate it. Do you intend to support research in the Eastern and Central parts of our country as well as in the West?

Mr. BLOCH. Let me comment on it. When I said I can't tell you where, it is simply that this information doesn't exist.

We have received five proposals and I don't know how they will rate in the peer review process. That is what I meant. But, let me assure you that the five proposals come from all parts of the country not just from one State.

Senator GORE. All right. Let's move on. You have now funded five academic supercomputer centers around the country.

I have been to some of them. And I tried to pay particular attention to this, again having had hearings on the House side on this. And there is a bottleneck in the supercomputer program, and that is the link between the university supercomputer centers.

The bit rate of telephone, regular telephone lines is so slow that the ability to transmit graphics, for example, or other functions that are high data users quickly exhausts the current communication links between these supercomputer centers.

I believe that the obvious synergy that can come from closer linkage means that improved communication links would be a very profitable investment for the country to make. Indeed, it may soon become prohibitively expensive to continue using the conventional telephone lines in this manner.

Are you now looking at options for the future networking of U.S. supercomputers?

Mr. BLOCH. Absolutely. Let me just review the situation with you. You are right, we have established five supercomputer centers.

We do not plan to establish any more in 1987. What we are concentrating on now is exactly the problem that you are citing; namely networking—networking not only between those centers but also between the users and the centers, wherever those users are located.

They can be on a different campus or they can be on a different continent. The program that we have in place for 1987 and 1988 is focusing very heavily on new investments in networking.

That is a bottleneck. It is also a very complex subject. It is also an area where technology moves very rapidly, although sometimes not as rapidly as one would like. It is also a very expensive area because it is not just the network itself, the carrier of the signal.

It has to do with work stations for access, the people to manage the network, and the establishment of standards so that people have easy access and user-friendly software. You can get access but how easy the access is is very important. So we are addressing these problems.

Senator GORE. The supercomputer is going to be to the information age what the steam engine was to the industrial age. And the nation which most efficiently utilizes its supercomputers will have a tremendous advantage. And our civilization will accrue the benefits.

If we are going to use them effectively, then the various research teams clustered around each of the supercomputers established must be able to work cooperatively with their counterpart teams clustered around the other supercomputers established in the country.

I have an initiative in this area which I would just call to the attention of my colleagues and the chairman to explore the creation of, in effect, superhighways for information just as superhighways in the fifties and sixties led to a tremendous increase in commerce.

A national investment in superhighways for information linking the supercomputers would have, in my view, a tremendous pay-off for this country. I have prepared a bill in to get a study going in this area. I hope that perhaps we can look at that a little bit later. I would appreciate any additional information you can supplement for the record on this.

One final question. I hate to abuse my time, but very briefly, I have had a particular interest in the ethics and values in science program. And your authorization act called for $1 million on this research. And yet I understand the actual number will be only $500,000. Could you explain that?

Mr. BLOCH. Yes. If you remember, Senator, we had some conversations on that last year. You are right in the numbers that you quoted. I want to say that continuation of this program was not included in the 1986 budget justifications nor specifically mentioned in the 1986 appropriation the Foundation received.

I wrote a letter in October of 1985, to the chairmen of the Senate and House Appropriations Committees indicating our intent to continue the support of that particular program at the authorized level of $1 million. We were instructed, however, not to continue support of this activity.

I wrote a second letter on January 16 asking the Appropriations Committee to reevaluate the situation. That is when the agreement of $500,000 for 1986 came about. So I think we have done the best under the circumstances that we could do.

Let me just remind you of two related items. We moved the program out of the STA directorate into the BBS directorate. Also, we are reorganizing the program in terms of content to focus very heavily on the area or risk in biotechnology, which as you know is a very important one.

I think what we have tried to do with the program is not scuttle it or not disregard it, but redirect it, put it under a different management where it gets a different focus. We have about 45 proposals in-house right now. I can't tell you how they stack up. They are being reviewed.

Senator GORE. In conclusion let me thank you for the responsiveness to the concerns I raised last year but urge you to assign a higher priority to this program even as those of us who support it work for a higher priority elsewhere in the Government.

It is ironic that the incredible advances in the hard sciences are accompanied by advances in the humanities that occur seemingly at a snail's pace. One of our tasks is to accelerate the development of ethical and legal and moral structures that can assist us in coping with the awesome implications of new advances such as those occurring in biotechnology and supercomputers and in other areas.

I think this concern is growing among the American people. I really think that it is in the best interests of our country and of NSF to respond to that concern by having not merely a symbolic program but a real program to see what can be done to address these kinds of questions.

Mr. BLOCH. Let me add one more note about that. You should look at us as a catalyst in this particular area. And I made that point last year. Because of the program as it existed for a number of years, many things happened in professional societies and scientific societies, in the private sector, even in the universities that probably wouldn't have happened otherwise.

So you should look at NSF as a catalyst in this area. We won't solve the total problem, because as you know, the problem is very large and complex.

Senator GORE. We need a larger catalyst. Thank you, Mr. Chairman, for your generosity.

Senator GORTON. Thank you, Mr. Bloch and Dr. Schmitt.

[The statement and questions and answers follow:]

STATEMENT OF HON. ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. Chairman and members of the subcommittee, it is a pleasure to meet with you today to discuss the FY 1987 budget request for the National Science Foundation. I want to thank you for the support which you gave to the Foundation's budget last year. But particularly I would like to commend you and your Senate and House colleagues for getting an Authorization bill passed after a hiatus of several years.

I'd like to take this opportunity to summarize and highlight our strategy. The problems with which we are faced, and the special opportunities which our budget request includes.

Mr. Chairman, I want to focus on the context for the 1987 NSF budget: the importance of basic research to the nation, the strategy underlying the 1987 request, and some highlights.

BASIC RESEARCH IN THE UNITED STATES

The Federal Government will provide about $61 billion for support of R&D activities in FY 1987. Basic research accounts for only $8.6 billion, or 14 percent of this total. Federal suppport of basic research is estimated to increase by 8 percent in FY 1987. Since a higher percentage increase is projected for support of development activities, the share of research dollars that is devoted to basic research is dropping.

Contrary to other countries, in the United States about half of all basic research activity takes place in colleges and universities. We have chosen to locate so much of the Federal support for basic research at our academic institutions because in this way we can ensure the continued production of top quality scientists and engineers for academia, industry, and government. As a consequence, higher education and research are inexorably intertwined; supporting one is supporting the other.

The President's Budget Request for NSF shows an increase of 15.6 percent above the New Obligational Authority provided for FY 1986 as altered by the Gramm-Rudman-Hollings process. This signals the emphasis this administration places on basic science and engineering as a force for present and future competitiveness, as a prerequisite for the products and services that improve the lives of our citizens, and as a base for building a strong national defense.

This increase occurs even in the face of large Federal deficits and efforts to reduce Federal spending because investment in basic science and engineering is essential to improving our competitiveness internationally and reducing our trade deficit.

NSF has a unique role in the Federal support of science and engineering research and education. Our programs provide support for promising ideas across all fields of science and engineering and complement the support provided by the more mission-oriented Federal agencies.

NSF accounts for less than 3 percent of the Federal support for total research and development. However, it provides nearly 17 percent of Federal basic research dollars and about 25 percent of the Federal support for basic research at colleges and universities. This support allows researchers to tackle problems that require longer term investments not directly driven by the need for specific applications. It is from support such as this that genuine breakthroughs occur, innovation is stimulated and Nobel prizes are earned.

PROBLEMS AND BUDGET STRATEGY

The problems that we must address are the following:

(1) Our support of basic research and education in science and engineering needs strengthening when one considers the increasing rate at which advances and new developments are taking place, and the increasing emphasis and significant progress that other nations are making in this area.

We are not attracting enough young people to science and engineering to assure an adequate supply in the future.

(3) Our investment in the infrastructure of science and engineering—equipment, instrumentation, and facilities—must continue.

The Foundation's budget strategy for FY 1987 addresses these issues. This strategy provides for continuity by maintaining balanced support for research of proven quality across all disciplines;

Ensures change by investing significant resources in a selected number of areas that offer particular promise for scientific and engineering advances; and

Stresses fiscal responsibility by leveraging Federal resources wherever possible and by phasing down or terminating activities of lower priority or lesser promise.

STIMULATING COMPETITIVENESS AND INNOVATION

Economic competitiveness is an important subject at this time in our Nation's history. We have gone from being a creditor nation to one with growing trade deficits. Trade protection, however, is not the answer; developing and being first in the use of new technologies is the answer. Therefore, support for basic research and education in science and engineering is essential. Even in the short term, investments in basic research will help to improve our competitiveness. In the longer run. Failure to provide substantial support for basic research and education is sure to have grave consequences.

Through support for such programs as the Engineering Research Centers, initiated in FY 1985, we are providing opportunities for industrial and academic engineers and scientists to work together in areas of inquiry which require a stronger fundamental research base for future advances. These centers also provide experiences for undergraduate and graduate students which can better prepare them for careers in industrial research. Six centers have been esablished. We will very shortly announce awards for four or five more, and the FY 1987 budget request includes support for an additional four centers.

There is great potential for long-term economic payoff in other research areas, including materials, chemistry, computer science and biotechnology. All of these areas receive enhanced support in FY 1987, both in ongoing base programs and through the special emphasis areas of computational science and engineering, biotechnology, and global geosciences.

Our efforts in support of research conducted by small businesses and of joint industry-university research ventures are directly aimed at encouraging innovation and building stronger links between basic research activities of today and economic advances in the future.

We cannot take leadership in science and engineering research and technology for granted. Our trading partners abroad are increasing very significantly their commitments to research and their efforts are paying off in increased world market shares. We must be willing to invest adquately to narrow the gap between research results and the marketplace. The efforts described above are illustrative of the NSF approach to contributing to the maintanance of a preeminent position for the United States in economic competition.

DEVELOPING SCIENCE AND ENGINEERING PERSONNEL

The human resource pool that will provide the scientists and engineers of the future is critically important. For the young men and women already in the career pipeline, NSF provides support for the initiation of individual research programs at colleges and universities, for postdoctoral opportunities, and for graduate research assistantships and fellowships. At the undergraduate level, and particularly the precollege years, where career decisions are not yet firm, the Foundation directs special efforts toward making scientific and technical careers attractive and attainable. In all of these efforts, increasing the participation of women, minorities, and physically disabled persons in scientific and engineering activities is an important Foundation goal.

Support for precollege science and mathematics activities is stabilized at the FY 1986 level. The FY 1987 program builds on, and continues, activities begun earlier. These include materials development, informal education, teacher preparation and enhancement, and studies and assessments. These activities are all consistent with the functional objectives as described in the reauthorization of the Education for Economic Security Act, P.L. 99-159. All of the science and mathematics fields taught at the K-12 levels are covered. In the teacher enhencement area, about 10,000 teachers per year are participating in projects. The goal of these activities is to improve the quality of precollege instruction in science and mathematics, provide meaningful out-of-school experiences for young people, and stimulate young men and women to consider careers in science and engineering fields.

The management study mandated in the FY 1985 Appropriation for NSF has just been funded. The study will be completed in 18 months, with several interim reports required. As information becomes available it will be used in updating and reformulating the Science and Engineering Education long range plan.

IMPROVING THE PHYSICAL INFRASTRUCTURE OF SCIENCE AND ENGINEERING

Advances in science and engineering are increasingly dependent on the equipment available to researchers. Instrumentation and facilities must be of the highest quality possible if we are to maintain our science and technology base and realize future advances.

In recent years, we have reduced or rescheduled several major capital investments in research facilities. This has been a necessary and appropriate response to financial constraints. However, it does not constitute an acceptable long-term policy for research support. This budget includes support for on-going capital improvements; no new starts are included.

Each facility improvement has been carefully examined to ensure that the support we are requesting balances the need for fiscal restraint and the scientific need for the facility. For example, the Cornell Electron Storage Ring upgrade will continue (although its completion will be delayed 1 year), while construction of the Michigan State University Cyclotron and the Indiana University Cooler Ring will be completed. Support for the construction of the very long Baseline Array will be maintained at essentially the FY 1986 level.

Modern research requires state-of-the-art instrumentation and equipment. Accordingly, the FY 1987 budget request includes funds for increased investment in discipline-specific research instrumentation programs and for an expansion of the College Science Instrumentation Program. Increases for instrumentation occur throughout the disciplines supported by the Foundation, with special attention focused on the biological sciences this year.

LEVERAGING FEDERAL DOLLARS

NSF continues in FY 1987, as in previous years, to leverage Federal dollars by encouraging and requiring the participation of private sector organizations, academic institutions, and State and local governments as partners in funding research and education. Some programs require contributions from these and other sources.

Examples of the successes we have achieved in attracting outside funding to complement and extend the support by NSF:

The six Engineering Research Centers established last year have generated approximately $13 million in industrial support:

The National Advanced Scientific Computing Centers which were also initiated last year have raised a 40 cent match for every dollar the Federal Government spends:

The $5.5 million provided for the FY 1985 College Science Instrumentation program awards will be matched by at least an equal amount; and

The FY 1984 class of Presidential Young Investigators has succeeded in obtaining nearly $11 million in matching funds.

So far during FY 1986, $1.9 million NSF investment in precollege instructional development has been matched by nearly $9 million from other sources.

THE NSF BUDGET REQUEST FOR FISCAL YEAR 1987

The strategy we have adopted is embodied in the Foundation's FY 1987 Budget Request, which totals $1,685.7 million or 13.2 percent above the approved FY 1986 Post Gramm-Rudman-Hollings Current Plan of $1,489.8 million. This Current Plan is composed of $1,458.3 million in New Obligational Authority [NOA] and $31.5 million deferred from FY 1985 for use in FY 1986 for Science and Engineering Education. The FY 1987 request is therefore 15.6 percent above the FY 1986 NOA. It includes: $1,479 million for Research and Related Activities, an increase of 14.3 percent; $117 million for the U.S. Antarctic Program [USAP], up 6.4 percent. A base transfer of $14.4 million was made to the U.S. Coast Guard to cover basic icebreaker services. Those funds include part of a $3.0 million increase in Coast Guard charges; $89 million, or a 5.1 percent increase, for Science and Engineering Education. The carryover of $31.5 million from FY 1985 into FY 1986 has been made part of the base for Science and Engineering Education; $0.7 million in Special Foreign Currency funds.

This Budget Request, if approved by Congress: Will maintain balanced support for research of proven quality across all disciplines; will allow significant increases for a small number of multidisciplinary special emphasis areas where additional funding can have a multiplier effect by establishing new institutional arrangements and capabilities for encouraging the collaboration that accelerate scientific productivity; will provide support for facilities which are an integral part of research activities in fields such as physics, materials, advanced scientific computing, astronomy, and the geosciences; will stabilize funding for the Science and Engineering Education activity, maintaining the FY 1986 level for graduate and precollege programs and an increase for the College Science Instrumentation Program.

SPECIAL EMPHASIS FOR FISCAL YEAR 1987

Four areas have been identified for special emphasis in FY 1987: three scientific research areas and one infrastructure area. The three scientific areas are biotechnology, computational science and engineering and global geosciences. Each is multidisciplinary in nature, and this demands collaborative efforts and sophisticated equipment. They are areas where additional funding can have a large multiplier effect by establishing new institutional arrangements for encouraging the collaboration that will accelerate and intensify scientific productivity. The fourth emphasis addresses the need to build a strong, diverse base, both of people and institutions, for the performance of research in the future.

BIOTECHNOLOGY

The biotechnology industry in the U.S. is a successful and growing enterprise. The U.S. is currently the world leader in many aspects of biotechnology. That leadership cannot be maintained without continued effort.

The success of commercial biotechnology relies heavily on the fundamental research base and is increasingly multidisiplinary in nature. Future advances will require: Enhanced development of the knowledge base, especially in areas with gaps that limit progress; and scientists and engineers with solid disciplinary training and skills, working in research environments that encourage multidisciplinary efforts.

The Foundation has increased support for fundamental biotechnology-related research over the past several years. Our first efforts were mainly aimed at increasing support for the plant sciences, including the establishment of a Plant Sciences Postdoctoral Fellowship Program. In FY 1985, attention was directed to the initiation of collaborative efforts between chemists and biologists to gain a deeper understanding of life processes. In the Engineering Research Center program an award was made to the Massachusetts Institute of Technology to establish a Center for Biotechnology Process Engineering.

For FY 1987, an increase of $20 million is requested over the FY 1986 level of $86.5 million. The incremental funds will be used for multidisciplinary research centers, multi-user equipment, and cross-disciplinary research and training programs.

COMPUTATIONAL SCIENCE AND ENGINEERING

Advanced research in many areas of science and engineering increasingly relies on computational methods to calculate, simulate, and model complex relationships, new concepts and ideas. This approach is complementary to the traditional experimental and theoretical approaches and provides an important new tool that enhances and accelerates scientific progress.

Until recently, the U.S. academic research community had limited opportunity to employ advanced computational methods because of lack of access to the most advanced computers. NSF began to address this need in FY 1985 with the establishment of national supercomputing centers and the provision of increased access to advanced computers to scientists and engineers from many disciplines. The effort has been largely single-investigator centered.

The FY 1987 emphasis encourages collaborative, multidisciplinary approaches to complex problems, thus capitalizing on the different perspectives of mathematicians, computer scientists and scientists and engineers from other disciplines.

In FY 1986, approximately $57 million will be allocated to computational science and engineering activities. In FY 1987, and additional $27 million is requested to establish new multidisciplinary teams, enhance existing centers and groups, and provide equipment and training opportunities.

GLOBAL GEOSCIENCES

The FY 1987 Budget Request seeks an increase of $18 million, over an estimated FY 1986 base of $17 million, for increased emphasis on global geosciences through a series of interrelated research efforts treating the earth as an integrated system of physical, chemical, and biological processes. Disciplines from the Atmospheric, Astronomical, Earth and Ocean Sciences Activity and the Biotic Systems and Resources subactivity of the Biological, Behavioral, and Social Sciences Activity will participate in the emphasis. There will also be significant participation in these activities by other agencies, including NASA, NOAA, and the USGS.

Studies of global ocean and atmospheric circulation, chemistry of the troposphere, ecosystem dynamics, biological diversity and productivity, an solid earth properties will be supported. The results will provide cohesive approaches to studies of these areas, create new data sets, and directly invigorate the constituent basic science disciplines.

The activities which will be funded through this emphasis are part of major international efforts to understand natural phenomena which cross regional and national boundaries. Increased understanding of these processes can lead to better predictive models for natural events such as the El Nino oceanic/atmospheric phenomenon, earthquakes and volcanic eruptions, and the consequences of human activity, such as acid rain and deforestation.

BROADENING PARTICIPATION IN SCIENCE AND ENGINEERING

The Foundation has a dual role in the support of the people and institutions that will be the performers of science and engineering research in the future:

To assure the excellence of our research, timely discoveries, and the quality of education to kept the U.S. competitive in tomorrow's world; and

To ensure that the broadest possible range of talent, both of people and institutions, is able to participate in scientific and engineering research.

In carrying out these responsibilities, issues of geographic, institutional, and personnel distribution are recognized as legitimate considerations in the development and maintenance of our science an engineering base.

The Foundation has employed targeted programs as well as efforts intergrated into all of the agency's program in its efforts to broaden participation in science and engineering. For FY 1987 this basic strategy continues and is enhanced.

Programs aided at increasing the participation of women and minorities are of both types; targeted mainstreamed. For example, the Visiting Professorships for Women program is located in the STIA Activity, as is the Research Improvement in Minority Institutions program. Both of these programs are centrally managed and budgeted. Both are maintained at the FY 1986 level. On the other hand, research initiation programs for minorities and women have been mainstreamed: disciplinary research programs are responsible for budgeting and managing these efforts while STIA provides Foundation-wide coordination and monitoring. The targets for both of these research initiation efforts are increased for FY 1987.

In FY 1987, a new program, Minority Research Centers of Excellence, is included in the budget request for the Scientific, Technological and International Affairs Activity. Through this program, a small number of minority institutions that have strong science or engineering programs will be assisted in becoming centers of excellence. These centers will conduct research, provide graduate training, work with associated undergraduate institutions, establish strong ties with nearby precollege teachers and schools, and serve as community resources for stimulating minority young people to consider careers in science and engineering.

For the last several years, NSF has increased its support of undergraduate research and education, largely through its focus on research in predominantly undergraduate institutions. In FY 1987 significant enhancement and extension of this effort is proposed. Undergraduate faculty and student research opportunities will be increased, regardless of the parent institution size and orientation. Support for undergraduate instructional instrumentation will be increased through the College Science Instrumentation Program. The focus on support for research at predominantly undergraduate institutions will continue in all the research programs of the Foundation.

Finally, the Experimental Program to Stimulate Competitive Research [EPSCoR] will be continued and enhanced. The program provides modest funds for planning and implementation to build science and engineering capacity in states that have not received large numbers of NSF awards. Up to eight awards will be made in FY 1987.

Other NSF efforts to build the scientific and engineering personnel pool for the future will continue. These include the Graduate Fellowships Program, graduate research assistantships, postdoctoral research associates, and Presidential Young Investigator awards.

Through these complementary approaches, NSF will contribute to building a scientific and engineering workforce that is characterized both by excellence and diversity.

CONCLUSION

Mr. Chairman, I hope that this overview provides a sense of the problems we are facing and the strategy we have chosen to address them. We are encouraged by the budget request level that the President has sent forward. We, of course, believe that science and engineering are keys to the future well-being of our country. I hope that the final action taken by the Congress on the National Science Foundation's FY 1987 Budget Request will help us ultimately to provide those keys for the Nation, and we ask for this Committee's support toward that end.

U.S. TRADE BALANCE IN HIGH-TECHNOLOGY AND OTHER MANUFACTURED PRODUCT GROUPS, IN CONSTANT DOLLARS

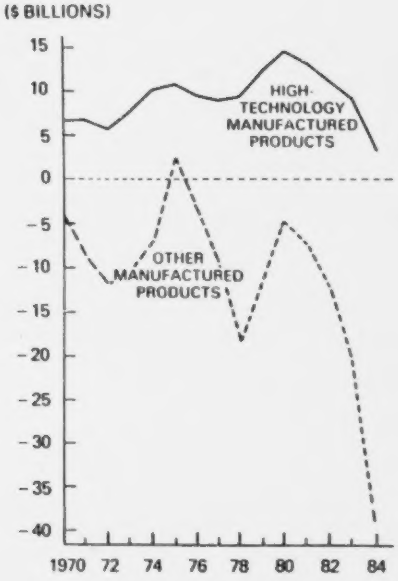
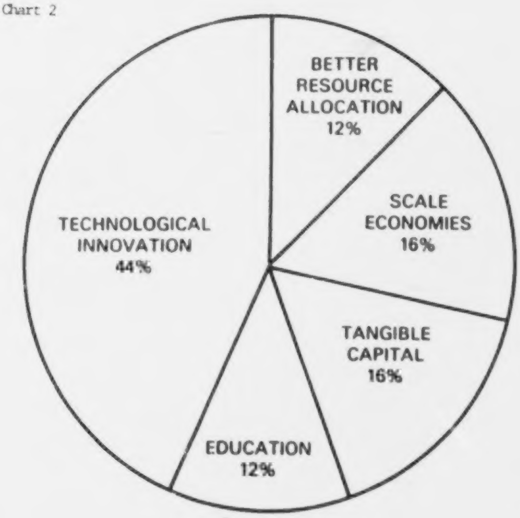


Chart 1

CONTRIBUTORS TO U.S. PRODUCTIVITY INCREASES

Chart 2



NATIONAL EXPENDITURES FOR PERFORMANCE OF RESEARCH AND DEVELOPMENT AS PERCENT OF GROSS NATIONAL PRODUCT BY COUNTRY

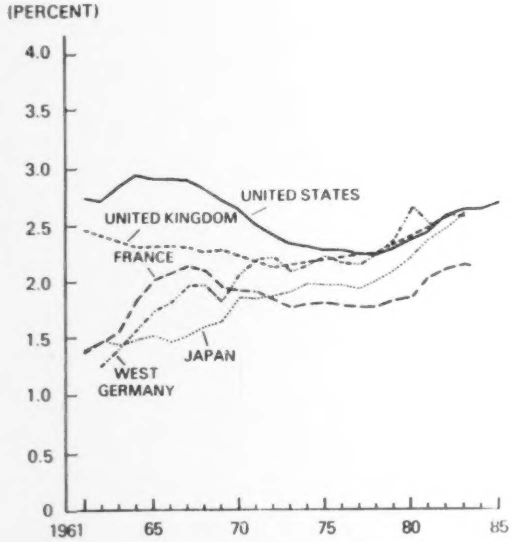


Chart 3

ESTIMATED RATIOS OF NON-DEFENSE R&D EXPENDITURES TO GROSS NATIONAL PRODUCT (GNP) FOR SELECTED COUNTRIES

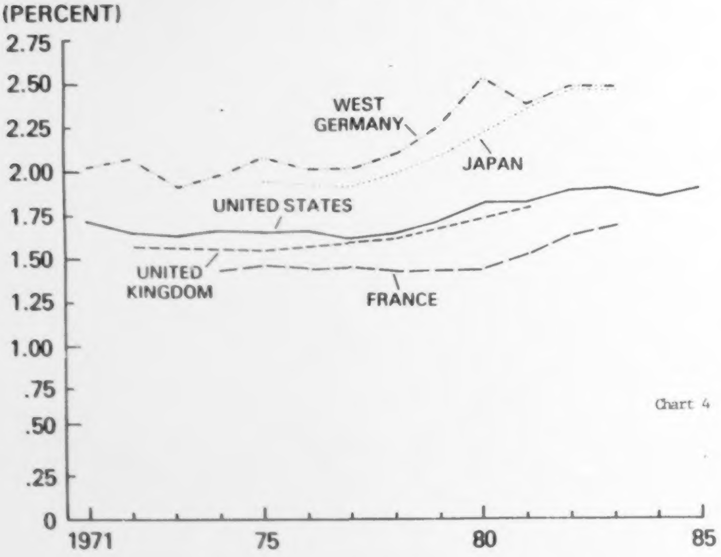
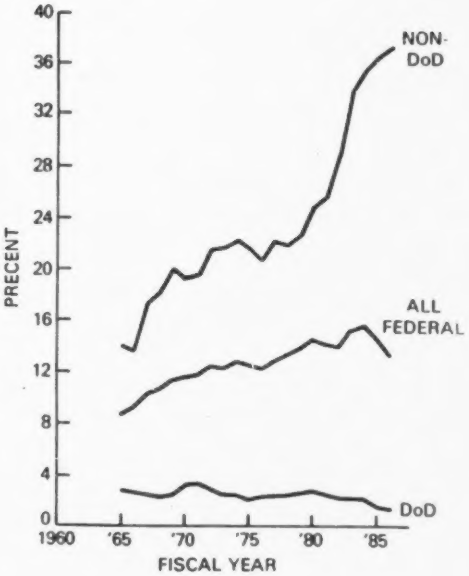


Chart 4

BASIC RESEARCH AS A PROPORTION OF TOTAL R&D BY CATEGORY



Source: National Science Foundation

Chart 5

SCIENTISTS AND ENGINEERS ENGAGED IN RESEARCH AND DEVELOPMENT PER 10,000 LABOR FORCE POPULATION BY COUNTRY

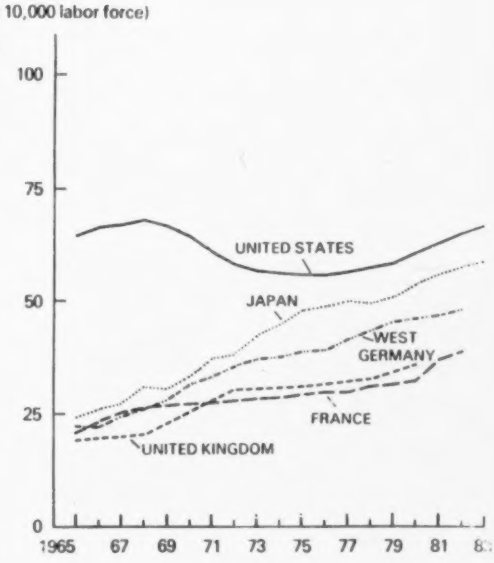
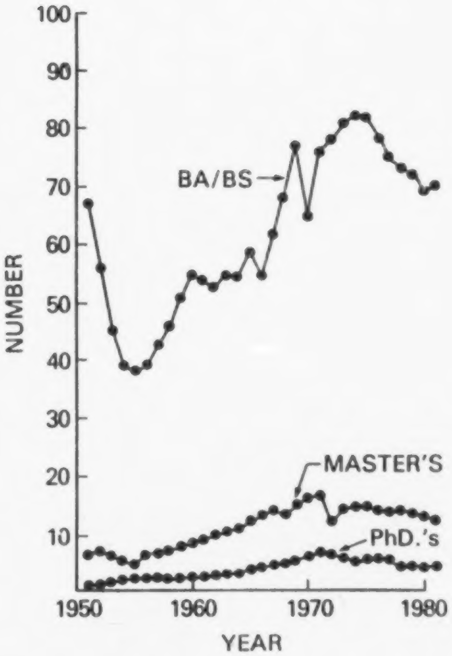


Chart 6

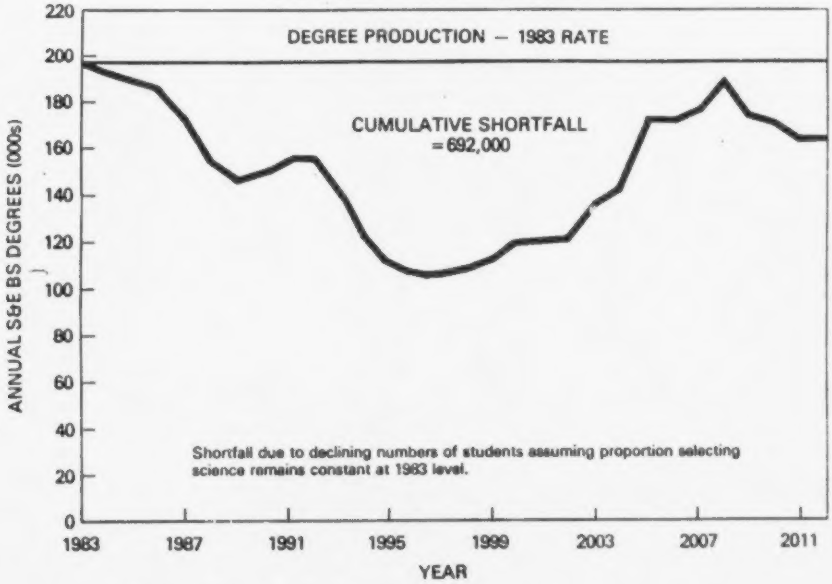
SCIENCE/ENGINEERING DEGREES PER THOUSAND IN APPROPRIATE AGE COHORT, 1950-1981

Chart 7



S&E BS PRODUCTION

Chart 8



Shortfall due to declining numbers of students assuming proportion selecting science remains constant at 1983 level.

Source: National Science Foundation, based on Census data.

DOCTORAL DEGREES AWARDED TO FOREIGN STUDENTS AS A PERCENT OF ALL DOCTORAL DEGREES FROM U.S. UNIVERSITIES, BY FIELD

ENGINEERING, MATHEMATICS, AND PHYSICAL SCIENCES

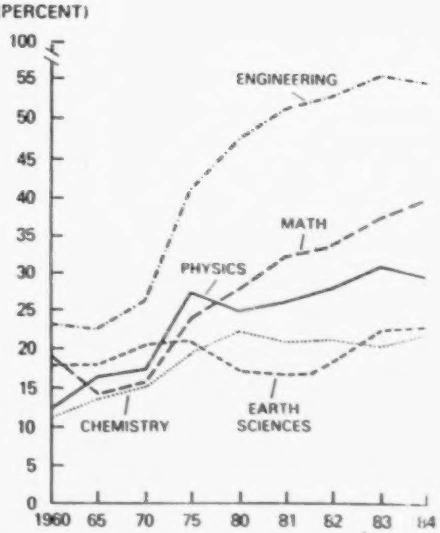
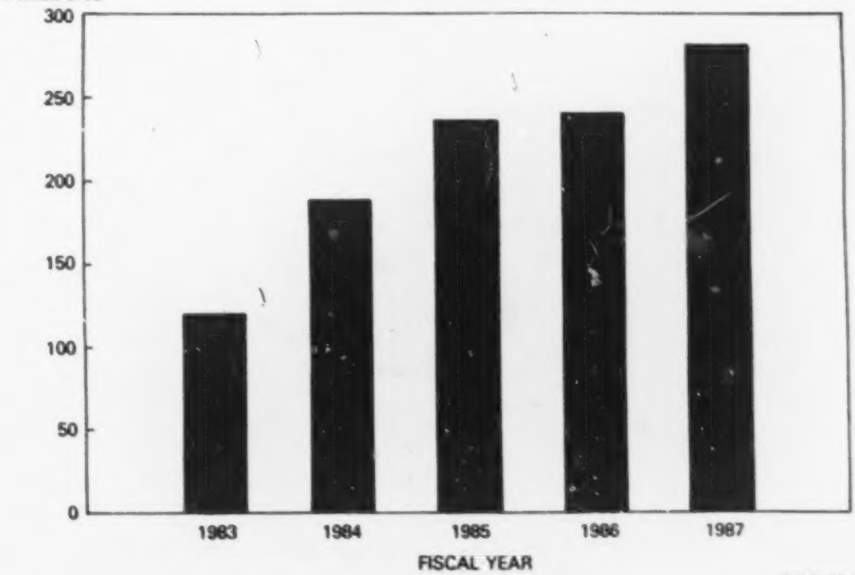


Chart 9

NSF EXPENDITURES FOR RESEARCH EQUIPMENT



O/D 86-142

Source: National Science Foundation, Office of Budget, Audit and Control

Chart 10

QUESTIONS OF THE COMMITTEE AND THE ANSWERS

Question.—Have you considered modifying your plans for astronomy for 1987 in light of the space shuttle accident?

Answer. The National Science Foundation realizes that the Space Shuttle accident will impose serious delays on a number of astronomy-related space missions. This is a severe blow to the hopes of the scientific community planning to use the intruments for research. Thus, it is all the more necessary to maintain the requested level for our strong program in ground-based astronomy so as not to endanger the long-term vitality and health of the field of astronomy.

Question.—The White House Science Council Report recommends using NSF's method of negotiating indirect costs with an investigator instead of NIH's method of adding indirect costs onto a research grant once awarded. How well has your method worked for you? Would you prefer the NIH method? Would you recommend yours to NIH?

Answer. First, it should be understood that NSF does not negotiate indirect cost with investigators. The total amount of each award is subject to negotiation, but the indirect cost rates are not negotiated on an individual award basis. Previously approved rates are applied to the appropriate direct costs for each award to determine applicable indirect cost amounts. Grantees occasionally volunteer to request a lesser amount of indirect costs within the total award amount on a particular grant.

NSF and NIH generally use the same indirect cost rate(s) to fund proposals at any particular institution. Essentially all the rates for educational institutions are established by either HHS or DOD. The basic differences in the way NSF and NIH use the rates are as follows:

(1) Proposals to NSF include requests for total project costs, both direct and indirect. NSF calculates the dollars to be funded for indirect costs on each grant using the latest available rate information. If the rate changes during the life of the award, the grantee may charge at the new rate. However, NSF will not provide additional funds for indirect costs and the grantee must assure NSF that application of the new rate will not reduce the scope of the project, increase the total cost to NSF, or decrease the contemplated period of support.

(2) We understand that proposals to NIH request only the direct costs of the project. NIH does not include an amount for indirect costs in their project awards. During the year they periodically calculate the amount due an institution for all its awards and provide a single payment, at the current indirect cost rate. Since rates have historically increased, the NIH method may include a larger amount for indirect costs than would be provided using the NSF system.

The NSF method has worked very well for us and appears to be preferred by investigators. We believe there are advantages in proposals and awards reflecting the total costs (direct and indirect) requested or funded for any given project. We have reviewed the NIH system from time to time in the past and continue to believe the system we use is best suited to our activities.

Question.—The issue of access to our academic supercomputer centers by certain foreign nationals is one of concern to us. What is the status of the discussions within the Administration on this subject?

Answer. The National Science Foundation, the Department of Defense, the Department of State, and other interested Federal agencies have been working to develop national policy on access to U.S. supercomputers by Soviet bloc nationals which will be both effective and realistic in protecting legitimate national security concerns, but not unduly compromise the traditional openness and free inquiry of our nation's campuses.

The policy which is being developed would apply to all U.S.-based supercomputers, not just those being funded by NSF. There appears to be general agreement among the agencies that the use of visa controls to carry out the policy is the best of a limited number of alternatives. Visas issued to Soviet-bloc scientists or engineers would be conditioned in effect upon their not seeking access to or otherwise using a supercomputer while in the United States. This approach would place the onus of enforcement properly upon the United States Government; universities and other private organizations would have no legal responsibilities in this respect and would not be asked or expected to be policemen.

The Foundation, together with a number of other interested agencies, supports a regime which is both administratively and legally feasible and which, we believe, strikes that balance between safeguarding the national security and preserving the traditional openness of scientific communications. Generally, the regime would:

(1) Bar nonresident aliens from Soviet-bloc countries from access to U.S.-based supercomputers.

(2) Enforce the bar by visa controls, as described above.

(3) Construe the bar to allow exchange students access to supercomputers for coursework asked of all students in a regular university course.

(4) Allow for case-by-case determinations to permit access for scientific research in fields with no direct defense or intelligence application for Soviet-bloc researchers not known to be actively engaged in intelligence collection.

(5) Include on an informal basis Guidelines for Supercomputer Center Security that codify good supercomputer security practices accepted by NSF-funded supercomputer centers.

The Department of Defense does not agree with points 3 and 4. They argue for a strict no-access regime. Discussions continue as we search for a policy satisfactory to all interested Federal agencies and the scientific and engineering communities.

Question.—The Earthquake Hazards Reduction Act directs the Foundation to fund research in applications, not just basic research. How much of your work under that Act is in applications? How well is your research coordinated with the U.S. Geological Survey, the National Bureau of Standards, and the Federal Emergency Management Agency?

Answer. Although most NSF-sponsored research projects are directed toward building a fundamental knowledge base, a significant portion of previous NSF research has found its way into the practice of earthquake engineering and applications in one to four years. The four research programs in earthquake engineering address important applications in siting and geotechnical systems, architectural and mechanical systems, structural systems, and earthquake systems integration.

NSF research results provide the bases for much of the application oriented 1985 Edition of the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings which is currently being distributed to the private sector. Other examples of NSF research used in applications include use of the experimental results from a research project in the seismic behavior of masonry walls for forming the basis of the Los Angeles City Ordinance that pertains to the upgrading of existing unreinforced masonry buildings. Another research project which is currently underway is directed toward the preparation of recommendations for design procedures and building code provisions for reinforced masonry construction. This is a cooperative project with Japan.

An important applications program supported by NSF is the National Information Service for Earthquake Engineering (NISEE) with components located at the University of California, Berkeley and the California Institute of Technology. NISEE disseminates earthquake engineering and related information through library services, computer software, and publications. This activity is instrumental in providing practitioners with the tools to design safer and more economical buildings of all types.

NSF's research activities are well coordinated with the U.S. Geological Survey, the National Bureau of Standards, and the Federal Emergency Management Agency. A primary method of coordination is through the Interagency Committee on Seismic Safety in Construction where NSF participates and serves on the Steering Committee. NSF also invites individuals from these three agencies to serve on research proposal review panels and also reciprocates. The four agencies activities are coordinated through the Interagency Coordination Committee of the National Earthquake Hazards Reduction Program. Joint four agency NEHRP planning sessions are held periodically and the next session will be held on June 10, 1986.

QUESTIONS OF SENATOR GOLDWATER AND THE ANSWERS

Question.—There are exciting technological advances happening in new telescope research. As a result of the reduced budget in astronomy, will there not be retrenchment of our progress of our world leadership in the field of astronomy?

Answer. The technology necessary to build optical/infrared telescopes with the light-gathering power of a single mirror 15 meters in diameter has been maturing rapidly over the past few years. Support of those developments through the Advanced Development Program of the National Optical Astronomy Observatories (NOAO) has been, and remains, a high-priority item within the Division of Astronomical Sciences. Available resources are being concentrated on the most critical issues, including the technology required to cast large (8-meter diameter), lightweight primary mirrors. This research, being carried out at the University of Arizona and funded in part by the National Science Foundation through a subcontract with NOAO, has attracted international attention and remains the leading effort to produce large, monolithic mirrors.

Question.—It is my understanding that the Field Report prepared by the National Academy of Science on Astronomy includes the National New Technology Telescope (NNTT) as a high priority item. Is the completion of the NNTT still a high priority item and do you have a timetable to complete this project?

Answer. The National Academy of Sciences' report "Astronomy and Astrophysics for the 1980's" (Field Report) found the scientific case for a New Technology Telescope (NTT) of the 15-meter class to be compelling. The specific recommendation of the report is: "The design studies necessary before NTT can be constructed are of the highest priority and should be undertaken immediately."

The technology development program being funded through the Advanced Development Program of the National Optical Astronomy Observatories (NOAO) is designed to undertake such design studies. It receives high priority within the budget of the Division of Astronomical Sciences. Both the scientific case for large optical/infrared telescopes and the progress of the technology development program were recently examined by a subcommittee of the National Science Foundation's Advisory Committee for Astronomical Sciences. They find an increasing need for such telescopes to make progress on a number of important research topics, and they urged continued and increased support for the design studies in progress.

When these studies have been completed at the level of detail necessary to support a proposal, it is expected that NOAO will present the National Science Foundation with a proposal to proceed with the project. It will be considered in competition with other proposals and in light of the priorities and budget situation at the time.

Question.—The schedule for finishing the Very Large Baseline Array (VLBA) stretched from 4 years to 9 years resulting in a doubling of the costs for the project and at the same time delaying the NNTT. What are your plans for finishing the VLBA?

Answer. Continuation of construction of the Very Long Baseline Array (VLBA) project at approximately the level of effort in the FY 1987 Request to Congress will lead to completion in 1994 at a total construction cost currently estimated at about $90M, assuming 4% per year inflation. The schedule anticipated in the FY 1985 Request to Congress was completion in 1989 at a total estimated cost of approximately $65M. All cost increases for the VLBA construciton are the result of slowdowns imposed by funding constraints. If it becomes feasible to speed up the construction funding FY 1988 and beyond, completion can be accomplished sooner than 1994 and will result in cost savings compared to the objection of $90M.

Question.—The Foundation released its report this year on Women and Minorities in Science and Engineering which said, among other things, that there is a widening gap betwen salaries of male and female scientists and engineers and that black scientists and engineers receive lower salaries and have a higher unemployment rate that whites. What is the National Science Board doing to encourage women, minorities, and the handicapped to pursue successful careers in science and engineering?

Answer. The National Science Board (NSB) has had a longstanding concern regarding the participation of women, minorities and the handicapped in the sciences and engineering.

To focus its concern, the Board established in 1975 a Committee on Minorities and Women in Science (later renamed the Committee on Minorities, Women and the Handicapped in Science) whose charge was to address issues and programs that dealt with efforts to bring members of these groups into science and engineering careers.

In 1985, the Education and Human Resources Committee was established in part to oversee the Directorate for Science and Engineering Education (SEE) and the new programs being established there and to subsume the duties of the former Minorities, Women and the Handicapped in Science Committee. By taking on this responsibility, the Committee enabled the concern of these groups to be considered in the broader context of all human resource issues and to receive greater attention.

The need for a larger and better educated workforce to carry out research and to develop and implement new technologies is a vital one for the Nation. Since the total pool of young adults that must supply this need will be reduced by about 20% over the next 10–15 years, it is particularly urgent that full use be made of those population groups—women, minority and handicapped—that have been seriously underrepresented among the sciences and engineering. The NBS in May 1985 established a Committee on Research Excellence and Breadth of Research Participation whose deliberations led to Board Resolutions which would have NSF support continued and sustained experiments and demonstrations of educational and informational activities that will: 1) influence more women and minorities to enter careers in mathematics, science and engineering; 2) prepare them thoroughly and adequately to evaluate this choice; and 3) encourage assessments and longitudinal studies of the impact of these interventions.

Recognizing the need for increased participation in science and engineering by these underrepresented groups, the Congress in 1980 passed the Science and Technology Equal Opportunities Act (P.L. 96-516) which directed the National Science Foundation (NSF) to facilitate their education and careers. The Act also established the Committee on Equal Opportunities in Science and Technology (CEOST), since renamed the Committee on Equal Opportunities in Science and Engineering (SEOSE), to advise the Director of NSF on programs to enhance participation and advancement of these targeted groups and to report annually to the Congress on the status and progress of women, minorities and handicapped persons in science and engineering fields. This Committee meets periodically with other NSF advisory committees to exchange information, and the Chairperson is regularly invited to participate in the meetings of the Board's Education and Human Resources Committee.

The NSF issued in August 1985 an organizational and management philosophy statement that established the framework within which the NSF would carry out its mission. That statement included a determination to provide for greater participation of women, minorities and the handicapped on the NSF staff, its advisory bodies, and as peer reviewers and grantees.

Further, the NSF issued a policy statement on affirmative action in September 1985 which derives from the philosophy statement noted above. Each office and directorate is charged with the responsibility of carrying out this mandate which deals with the internal hiring and personnel practices as well as activities designed to increase the participation of women, minorities and handicapped in the program activities of the Foundation.

In addition to this general directive, the NSF has several programs specifically designed to support women, minorities and handicapped in the sciences and engineering.

The Research Initiation and Improvement (RII) programs of the Scientific, Technological and International Affairs (STIA) Directorate support research and related activities that strengthen the Nation's human and institutional resource base for scientists and engineers. The objectives are: 1) to increase opportunities for women, minority and physically handicapped investigators and research faculty from predominantly undergraduate institutions to participate more fully in the Nation's scientific and engineering research enterprise; 2) to improve access to scientific and technical resources by institutions that currently underutilize such resources; and 3) to help identify and understand the human and institutional resources that contribute to the Nations scientific and engineering needs, the barriers and problems that exist and the opportunities and solutions available, and to assist the Foundation in planning and managing NSF programs that address them.

These broad objectives are carried out specifically in the following programs: Visiting Professorships for Women (VPW); Research Improvement in Minority Institutions (RIMI); Minority Research Centers of Excellence (proposed for FY 1987); Minority Research Initiation (MRI); Research Opportunities for Women (ROW); Faculty Awards for Handicapped Scientists and Engineering (FAH).

In addition, the Minority Graduate Fellowships program, administered by the Science and Engineering Education (SEE) Directorate, offers support for advanced study in all fields of science and engineering to members of ethnic minority groups who are underrepresented in the science talent pool.

The National Science Board will continue to encourage the participation of women, minorities and the handicapped in science and engineering by actively reviewing directorate plans, advising on strategic issues and programs, and by reviewing program initiatives and major new projects/facilities with respect to science and engineering education programs for these underrepresented population groups.

Questions of Senator Riegle and the Answers

ENGINEERING

Question 1.—Many officials in Congress and the executive branch have expressed strong support for the new Engineering Research Center program. For example, Dr. Keyworth, the former presidential science advisor, often said that we should create 50 of these centers. The Foundation itself has been supportive: half of your proposed FY 1987 increase for the entire Engineering Directorate would go to ERCs. Yet I am disappointed that we have been able to fund only 11 of these valuable centers so far.

Why don't we have more of these centers? How many do you believe that NSF eventually will be able to support? Should we encourage other federal agencies to support engineering centers at American universities?

Answer. The Engineering Research Centers program was established with the guidance of the National Research Council and the support of the Office of Science and Technology Policy, and the Congress. Recommended was the establishment of 25 of these centers with annual budgets ranging from $2.5 million to $5.0 million. NSF initiated the program with $10.0 million in FY 1985, this was raised to $23M in FY 1986, and is proposed for $35M in FY 1987. These funds have been used to establish new centers and support ongoing centers. Six centers were begun in FY 1985 and now have operating budgets between $1.2M and $3M; another five were begun in FY 1986 with operating budgets ranging from $1.2M to $2M. The FY 1987 budget will provide for four new centers. Further plans are to establish 5 more in FY 1988 and to reach the initial goal of 25 centers in FY 1989. The growth in the Engineering Budget has not been sufficiently large to accommodate both faster growth in the ERC program and an appropriate level of support for the other activities of the Directorate.

NSF has actively encouraged other federal agencies to mount programs to support engineering research centers. While the Department of Defense and others are beginning such programs, the centers are necessarily related to the missions of these agencies. NSF's Engineering Research Centers are focused on both engineering research and education underpinning technological innovation in a broad range of industries critical to the competitive position of U.S. industry.

Question 2.—Many universities around the country have expressed great interest in the Engineering Research Center program. They have submitted almost 250 proposals over the past two years.

What efforts has NSF made to work with the unsuccessful applicants so that any future proposals they submit will be more competitive?

Answer. The response of the engineering research community to the Engineering Research Centers program announcements has been enthusiastic, 244 proposals, covering a broad range of topics from a wide range of institutions. Some 30 percent of these proposals were highly recommended for support by the review process. Budgetary limitations have restricted the number supported to 11, or only 4% of the total submitted.

The process of writing a proposal, forming a cross-disciplinary team and bringing industry on campus to help structure a center has produced important changes on campus that sometimes have a life of their own beyond the small number of centers NSF can support. While this is an important spin-off from the establishment of the ERC program, we have also assisted the community in developing more competitive proposals. The ERC program organized a series of regional briefings during the summer of 1986 to inform the community of the key features of an ERC and respond to questions about the requirements of the program. The review process itself is an important feed-back to unsuccessful centers. Each stage of the review is documented and the reviews are returned to the proposing center director. A number of prospective center directors visit the ERC program staff to discuss the program and their plans for developing proposals.

While we do not want all ERCs to operate in identical modes, we do provide materials briefly describing the structure of each operating ERC and copies of successful proposals are also available.

Each year a major symposium is held through the auspices of the National Research Council, presenting a series of briefings on the ERC program by NSF personnel, science policy officials, and members of the industrial community. Each ERC reports on its plans and progress at these symposia. The symposium results in a proceedings which is published by the National Research Council and widely distributed by the NRC and the NSF.

INTERNATIONAL SCIENCE

Question 1.—Japan is our most formidable economic competitor. The Japanese also increasingly fund basic research, making them innovators as well as imitators. NSF seems interested in this issue, and recently worked with the International Trade Administration to prepare several reports about trends in selected areas of Japanese technology.

What role does NSF play in monitoring and reporting on the scientific and technological accomplishments of other countries, especially Japan? Which specific reports has it prepared on this subject? Would you like to see the Foundation do more in this area?

Answer. In 1984, NSF initiated a new effort to expand its activities in collecting, analyzing and reporting international comparisons of S&T resources data including indicators of inputs into the S&T system, outputs and S&T impacts. Initial focus has been on the large R&E-performing countries such as Japan, France, West Germany, the United Kingdom, and the Soviet Union. NSF has supplemented data acquired from international organizations such as the Organisation for Economic Co-operation and Development with information acquired through extramural research awards, intramural research efforts by staff, and personal contact with government officials and researchers from foreign countries.

Special emphasis has been placed on Japan in that an additional staff person was hired in 1985 who is fluent in Japanese and knowledgeable about the Japanese S&T enterprise. A number of extramural research projects are underway which will provide comparative data on Japan. For example, a project to identify leading-edge Japanese science and technology and a comparative study of U.S. and Japanese engineers.

Information on international S&T activities is distributed through several published NSF reports such as *Science Indicators, National Patterns of Science and Technology Resources, Science and Technology Data Book,* and the *International Science and Technology Data Update.* Additional studies include *Performer Organizations and Support Strategies for Fundamental Research: United States, France, West Germany, United Kingdom, Japan, Soviet Union* and *Research Policies and Strategies in Six Countries: A Comparative Analysis.*

Special studies have been supported to analyze the research systems of other industrial countries, such as an SRI International review on "Performer Organizations and Support Strategies for Fundamental Research: Unite States, France, West Germany, U.K., Japan, the Soviet Union." In addition, models of research progress in scientific fields, (such as mathematics and microelectronics) have been used to assess foreign capabilities.

NSF long has had a liaison office in Tokyo. In recent years the NSF/Tokyo Office has stepped-up its reporting capabilities on developments in Japanese S&E. Since 1982 nearly 100 reports have been generated on ongoing work in Japan and changes in Japanese policy for research in science and engineering.

Recent attempts have been made at the U.S. Embassy/Tokyo to assign particular S&E reporting responsibilities to specific offices. The attached list (Item A) contains the title of reports prepared by the NSF-Tokyo office. In addition to these reports, NSF/Tokyo prepares monthly Research News Clips on articles appearing in the Japanese press on science policy issues. Literature Search Reports on S&T items in Japanese journals and industrial in-house reports are abstracted in English as requested, primarily by NSF offices.

Through grant awards, NSF has also funded studies such as the recently completed (June 1986) National Academy Press Report on Advanced Processing of Electronic Materials in the U.S. and Japan. In conjunction with Defense Advanced Researh Projects Agency (DARPA), and previously in FY 1984 with the Department of Commerce, NSF has supported a number of evaluations of Japanese high-tech areas through the so-called Japanese Technology Evaluation Program (JTECH).

These studies have been conducted in the areas of computer science (1984), biotechology (1985), mechatronics (robotics, 1985), opto- and micro-electronics (1985), telecommunications technology (1986), and advanced materials (1986).

Question 2.—We also face the related issue of access of Japanese research projects and laboratories. American universities are quite open to visitors, while we hear that Japanese research facilities are not as accessible.

What can NSF do, through scientific exchange programs and other means, to provide Americans with greater access to university and government-supported research in Japan?

Answer. Through the United States-Japan Cooperative Science Program, exchanges of investigators between university laboratories do take place on a regular basis. NSF has had relatively little difficulty in gaining access for U.S. scientists and engineers to Japanese government laboratories. Perhaps this "ease of access" has been facilitiated by the mission NSF in supporting basic or fundamental research activity as opposed to research focused toward commercial applications. Since 1985, Japanese Government agencies have fostered "internationalization" in government laboratories by further encouraging foreign investigators to use these facilities, many of which are unique in the world. NSF-funded U.S. scientists and engineers have also enjoyed access to such unique government laboratories in Japan as the High Energy Physics (KEK) facility and the Earthquake Mitigation Facilities at Tsukuba, the Institute for Physical and Chemical Research (RIKEN) Science and Technology Agency laboratories, and the National Institutes at Okazaki. These laboratories are similar to our Brookhaven, Fermi, Oak Ridge, etc., national laboratories. NSF has completed negotiations with the Japanese Ministry for International Trade and Industry (MITI) to exchange visits between Japanese and American computer scientists working through the ICOT 5th Generation Computer Laboratories in Japan.

Motivated by a mutual concern of NSF and several other government agencies (ONR, AFOSR, Commerce, Energy) that information gathered about S&T in Japan was not being adequately disseminated, inter-agency discussions have been initiated. The establishment of an electronic bulletin board for disseminating trip reports and other information about Japanese research is being explored by this interagency working group.

Japanese industrial laboratories also provide access to American scientists and engineers. Report Memoranda #86 and #92 (attached) identify Japanese companies willing to receive American researchers.

Question 3.—The United States has entered a new era of international collaboration in science. The United States Western Europe, and Japan are collaborating in several areas. The President also envisions some cooperation with the Soviets. After the recent summit, the two countries discussed possible collaboration in fusion research. Yet we also hear objections to collaboration, even with the allies, on the grounds that it might eventually give American technology to our adversaries.

What is your view on this subject? Is it possible to increase international scientific collaboration, even with the Soviet Union, without jeopardizing national security?

Answer. International scientific collaboration is of great importance to the United States and to the progress of science. The scientific discoveries depend on the best people and their research, no matter where they are located. Therefore, as a guiding principal, the National Science Foundation is in favor of pursuing in the international scientific collaboration.

Productive international scientific collaboration depends on the fact that all participating parties benefit from such a collaboration. It can not be a one-sided activity; the fruits of collaboration must be obvious to all.

There are instances where national security would be jeopardized, if collaboration would take place on specific subject matters or early disclosures could result in an advantage to our adversaries. These instances must be decided on a case-by-case basis. They apply primarily to applied research or developmental areas and less to basic and fundamental research activities.

Guarding against disclosure which is not in the interest of the nation should not deter us, however, from fostering in general and specific terms international cooperation where mutual benefits can be assured from such an effort.

Questions of Senator Gore and the Answers

GENERAL

As we discussed at the hearing, I would be grateful if you would submit several items for the record. They are as follows.

Question.—How much money will the Foundation spend in FY 1986 on "greenhouse effect" research? Please include both the research supported at the National Center for Atmospheric Research and research support by other NSF programs. What level of research support do you plan for fiscal year 1987? What specific scientific questions will you focus on?

Answer. Global warming which results from increased concentrations of carbon dioxide and trace gases in the atmosphere is often referred to as "the greenhouse effect". The study of carbon and other elements as they cycle through the atmosphere, oceans, and solid earth is fundamental to understanding climate and climate change.

During FY 1986, the National Center for Atmospheric Research (NCAR) will be conducting research on the greenhouse effect of carbon dioxide and other chemicals in the atmosphere at an estimated level of effort of $1.6 million. Of this, NSF is providing $1.1 million, and other agencies (primarily the Department of Energy), $0.5 million. These funds support field and laboratory analyses, computer modeling and other services, and research salaries.

In addition to the ongoing research effort at NCAR, NSF grant programs in Geosciences and Biological, Behavioral and Social Sciences support the following areas of climate research related to carbon dioxide and trace gases: carbon cycle measurements, carbon dioxide and climate modeling, vegetation response to carbon dioxide and climate, and other effects (e.g., sea level changes).

The total NSF support for these research grant activities was $4.9 million in FY 1983, $5.3 million in FY 1984, and $5.2 million in FY 1985. It is anticipated that the FY 1986 level of support will be about $5 million.

In the FY 1987 NSF Budget Request, the Global Geosciences thrust ($18.2M) includes several programs aimed at understanding climate and chemical cycles in the global environment. The Tropical Ocean/Global Atmosphere (TOGA) Program will examine the coupling of physical processes between the atmosphere and oceans. The World Ocean Circulation Experiment (WOCE) will include study of the mechanisms for transfer of heat and chemicals within the oceans. Aspects of the production, transformation and disposition of chemical constituents, and their interaction with living organisms, will be studied in the Global Tropospheric Chemistry, Global Ocean Flux, and Global Ecosystem Dynamics programs.

Question.—Scientists have discovered an "ozone hole" over Antarctica. Will NSF now give research on this problem a high priority? What kinds of research projects will you undertake?

Answer. The ozone hole in the atmosphere that has appeared in the Antarctic Spring over that continent for the last several years is being studied this year as a major priority. This involves British scientists, Japanese scientists, and those of other nations, as well as U.S. scientists. The international Chemical Manufacturers Association is also involved and is providing some of the research support. The U.S. part of the project will be supported by the National Aeronautics and Space Administration, the National Science Foundation, and the National Oceanic and Atmospheric Administration as a concerted special effort.

Current plans call for NASA, NSF and NOAA to support research and for NSF/Antarctic Programs to provide antarctic logistics and coordination. The project includes both examination of satellite data and ground-based science such as the launching of balloon-borne ozone sondes from several antarctic stations. The aim is to collect data that will provide an explanation of this seasonal phenomenon for which several hypotheses exist. A sizeable field team will be assembled and taken on special flights to Antarctica in August, 1986. It will then be in position to make key observations at the ozone depletion maximum in September and October.

This is one of a number of high priority projects in the polar regions that are concerned with atmospheric and climatic change.

Question.—We discussed NSF's ongoing review of possible networking systems to link the nation's academic and federal research supercomputers. Could you please summarize efforts in this area. Also, do you believe that a comprehensive review of long-term networking options would be valuable?

Answer. The Foundation's ongoing review of networking systems began as a companion thrust of it's initiative on Advanced Scientific Computing in the early months of 1984. A network providing remote supercomputer access was to be developed in two phases. Phase I was developed by using conventional network technology and by expanding existing viable networks. Phase II will concentrate on high bandwidth services using satellite transponder facilities and optical fiber trunks as they become available. NSF surveyed both commercial and private networks which met the requirements for broad access and functional capability. Among these are:

ARPANET.—Arpanet was begun by the DoD as an experiment in resource sharing, providing high bandwidth (56,000 bits per second) communication links between major computational resources and computer users in academic, industrial, and government research laboratories. In October 1985, NSF and DARPA signed a memorandum of agreement to expand the number of ARPANET connections and to allow supercomputer users to use the ARPANET to access NSF supercomputer centers and to communicate with each other.

CSNET.—In the spring of 1980, CSNET, the computer science network, was defined as a logical network made up of several physical networks (including the ARPANET) with various levels of power, performance, and cost. More than 165 university, industrial, and government research groups now belong to CSNET. The Foundation is supporting research into extending and improving CSNET services at low cost to research departments.

BITNET.—BITNET, a store and forward network, allowing files and messages to be sent from computer to computer was created in 1981. By 1985 the number of computers connected was expected to exceed 600, at more than 175 institutions of higher education. The network has grown rapidly because of the simplicity of adding nodes by merely acquiring a 9,600 bits per second leased line to an existing node. BITNET, with NSF support, is examining ways to provide ARPANET like services by upgrading the line bandwidth (from 9,600 bits per second to 56,000 bit per second) and by adding multiple alternate links.

MFENET.—The Department of Energy's magnetic fusion energy network established in the mid 1970's uses 56,000 bits per second satellite links to the Magnetic Fusion Energy Center's supercomputers at Lawrence Livermore National Laboratory.

Other Private or Government Networks.—Other networks of interest include the Space Plasma Analysis Network (SPAN) and the planned Numerical and Atmospheric Sciences network used by National Aeronautics and Space Administration researchers. Many informal network interconnections have sprung up among various scientific and engineering disciplines, such as those used by the high energy physics community.

Commercial Networks.—NSF carried out a detailed study of available commercial common carrier networks including Telenet, Tymnet, Uninet, BCSNet, and others. At the present time commercial networks do not offer adequate services for computer-computer communications, but are used extensively for terminal access to the national supercomputer and resource centers. Talks continue with the major vendors such as AT&T, IBM, ITT, etc. on future integrated network services and other communications offerings.

The investigation of existing networks influenced the evolution under NSF auspices of an internet, or network of networks, based on a standard set of communication protocols used in the DOD model. This use of the internet concept has led to the implementation or planning of several memoranda of agreement with other Federal agencies notably DARPA, DOE, NASA, and the Departments of the Army and the Navy to share supercomputing and networking resources.

Recently, the FCCSET committee on Very High Performance Computing set up a subcommittee to address issues related to interconnection strategies and interoperability among the various agency networks, with a strong motivation to insure adequate supercomputer access to the academic research community.

As computing speeds and complexity of attempted computation grow, it is certain that many users will wish to transmit results of their computations in the form of high density graphics or other images. Others will want to access or transmit very large data sets on storage systems remote from the user site. Effective transmission rates must be greater than the 1.5 million bits per second achieved by using the current land line technology, and much higher than the 9.6 and 56 thousand bit per second transmission rates of the available commercial and private networks. The Foundation plans to study alternative technologies and will happily lead or participate in a comprehensive review of long-term networking options in league with other Federal agencies and organizations such as the National Academy of Sciences.

ANTARCTICA

Question 1.—As I understand current arrangements, the Foundation is the lead U.S. agency in Antarctica. You get logistical support from the Navy and the Coast Guard, but in most cases reimburse them for their services.

How did it come about that NSF is the lead agency? And do you have adequate resources and legal authority to represent the U.S. interests on the continent, particularly as growing numbers of tourists begin to visit?

Answer. The NSF is charged by a Presidential memo of February 5, 1982 with budgeting for and managing the entire U.S. program in Antarctica so that the program may be managed as a single package. The memo also stated the importance of science as a part of the U.S. presence in Antarctica and the need to minimize cost effectiveness. This memo was a logical extension of National Security Decision Memoranda 71 of 1970 and 318 of 1976. The reasons set forth above—management as a single package, importance of science, and cost effectiveness—are major reasons for the present arrangement. The Navy and Coast Guard are among those providing operational and logistic support as requested by NSF on a reimbursable basis.

Resources have been provided at a reasonable level though needs tend to exceed them, making decisions on priorities and deferrals necessary as a regular part of the program.

The question of legal authority and tourism has multiple aspects. With respect to criminal jurisdiction in Antarctica, the Antarctic Treaty generally provides that jurisdiction rests with the country of the individual's nationality. The recent extension of U.S. criminal jurisdiction over U.S. nationals in Antarctica under the special maritime law is consistent with the Treaty. Our legal authority to enforce the Antarctic Conservation Act is an additional matter. It does extend to U.S. tourists and is adequate to that end. However, the current legal arrangements may prove to be imperfect and the Executive Branch may in the future recommend to the Congress additional measures with respect to Antarctica.

Question 2.—Some of the aircraft and buildings used by the Antarctic program are very old. Some of your seven airplanes, for example, date from the 1950s. I understand that the radio gear on one plane is so old and unreliable that Los Angeles International Airport has banned that plane. Some of the living quarters at McMurdo Station on the edge of Antarctica apparently are canvas-covered buildings dating from the Korean War.

Do these outmoded aircraft and building pose a safety hazard, given the harsh climate in which they must operate? What steps do you propose to modernize the planes and improve the buildings?

Answer. With respect to the aircraft: Two LC-130F aircraft operated by VXE-6 and owned by NSF are of 1950's vintage. In May 1983, these aircraft were declared as non-mission capable because of poor reliability in electrical, communications and navigation equipment. Because of several instances of communication and/or navigation system failure, these aircraft were restricted from operating in all high density air traffic areas, including Los Angeles. One aircraft was immediately refurbished, at an approximate cost of $1M, with minimal avionics/wiring improvement to provide six deployable aircraft for the following operating season in Antarctica. The second aircraft is presently undergoing a similar upgrade that is scheduled for completion on June 25, 1986.

In the long term, these two aircraft will undergo a substantial structural modernization for which long leadtime procurement has been started. In addition, all seven aircraft will undergo avionics upgrade to standardize the aircraft with state-of-the-art avionics replacing vacum tube with solid state equipment. Funds in the amount of $5M for design and procurement of components are included in the FY 1987 budget. Further funding for this purpsoe will be needed in FY 1988 and major work on the aircraft will commence in 1989 and continue during regularly scheduled maintenance periods through 1992. This should increase the reliability and extend the life of the LC-130 fleet.

With respect to living quarters: The canvas-covered buildings referred to are the Jamesway Shelters which resemble a small canvas quonset hut. Because of the shortage of berthing at McMurdo, there are presently eleven Jamesway Shelters serving to berth approximately two hundred people.

In 1979 and 1980, five modern wooden-framed dormitories were completed. Two permanent steel-framed dormitory structures are now under construction at McMurdo Station. Completion of these buildings is scheduled for February 1988. When completed, these two buildings will provide adequate berthing in modern fire-resistent structures for 236 persons. Additional dormitories will allow demolition of the semipermanent wooden berthing buildings erected during the late 1950's and early 1960's.

QUESTIONS OF SENATOR ROCKFELLER AND THE ANSWERS

Questions.—I understand that the NSF Astronomy Committee recently expressed alarm over the low level of support for astronomy in NSF's FY 1987 budget request.

Can you tell us what advice you gathered in deciding on the budget proposed for astronomy? Why did astronomy received a lower percentage increase that other parts of NSF?

Answer: In developing budget proposals, the National Science Foundation receives advice from many sources: advisory committees, the scientific community at large, professional organizations, NSF staff, and others. Input from these sources is used to develop priorities for consideration by the National Science Board (NSB). The final budget request is then shaped using NSB guidance along with information from the Office of Management and Budget and the Office of Science and Technology Policy.

Four areas were chosen for emphasis in the FY 1987 Budget Request: (1) Biotechnology, (2) Computational Science and Engineering; (3) Global Geosciences, and (4) Broadening Participation in Science and Engineering Research and Education. The Astronomical Sciences (AST) will participate in both the Computional Science and Engineering and the Broadening Participation in Science and Egnineering Research and Education emphases.

Over the past decade AST has received significant budget increases when compared, for example, to Earth Sciences, Ocean Sciences, and Atmospheric Sciences. In FY 1984, the Foundation began a conscious effort to elevate the level of funding for earth science, specifically for research on the continental lithosphere. As a follow on, an emphasis in global geosciences was initiated for long-term research into the global ecosystem. Atronomy does not participate in either of these initiatives. At the same time, the Field Report endorsed initiation of the Very Long Baseline Array (VLBA), which NSF did in FY 1984. This remains the highest priority project in AST and funds for it have been included in the FY 1987 Budget Request.

Choosing among areas of scientific opportunities for budget emphasis is difficult task but one which must be done. It is inherent in this process that some areas will receive higher priority than others from year to year.

NSF's Field Committee report make several recommendations regarding support of ground-based astronomy during the 1980s.

Question.—What are your plans for continuing to implement these recommendations for ground-based astronomy?

Answer. The Field Committee report, "Astronomy and Astrophysics for the 1980s," was a study by the National Academy of Sciences and was jointly supported by the National Aeronautics and Space Administration (NASA) and by the National Science Foundation (NSF). NSF has lead responsibility for implementing the recommendations for ground-based astronomy.

The recommendations for ground-based astronomy include: strengthening the base program ("Prerequistes") construction of the Very Long Baseline Array (VLBA); design studies leading to a large (15-meter-class) optical/infrared New Technology Telescope; moderateaperture (2- to 5-meter-class) optical/infrared telescopes; a 10-meter submillimeter-wave anatenna; and other smaller programs.

The Foundation is supporting construction of the VLBA at the National Radio Astronomy Observatory. Construction began in 1985 and, at the present rate of funding, is projected for completion in 1994 at a total cost currently estimated at $90M. This schedule could be accelerated with more timely completion and cost savings if a speed-up of the funding schedule becomes feasible. In addition, a program of technology development for future large optical/infrared telescopes is being supported at the National Optical Astronomy Observatories in conjunction with the University of Arizona. Proposals for moderate-aperture optical/infrared telescopes are being considered on their scientific merits on a case-by-case basis. A 10-meter submillimeter-wave antenna is nearing completion on Mauna Kea, Hawaii, under the aegis of the California Institute of Technology.

Senator **Gorton**. Dr. Bogorad is next. I regret to say at this point I don't think we are going to be able to complete this hearing since the Chair is going to have to leave at noon.

So, Dr. Bogorad, we are going to ask you to limit your comments to 5 minutes and questions on this round will have to be limited to 5 minutes as well.

STATEMENT OF DR. LAWRENCE BOGORAD, PRESIDENT-ELECT, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Dr. **Bogorad**. I would like to thank you, Mr. Chairman, for allowing me to appear. I would like to thank you for the opportunity to submit a statement, which we filed and which is rather lengthy.

I am the professor of biology at Harvard University but here I am presenting a statement in my capacity as president-elect of the American Association for the Advancement of Science.

We are an umbrella-like organization whose members span in all fields of science and engineering and our affiliated organizations have a total membership of about 5 million.

So we have very many interests in common with the NFS. We are a broad-based science organization, interested in basic and applied research in all scientific and engineering disciplines. And we are concerned with science education at all levels of our system and in the scientific literacy of the American public.

Above all, we share with this subcommittee and the National Science Foundation a strong interest in maintaining the vigor of the American scientific enterprise. In our formal statement we have addressed a number of specific issues in the National Science Foundation budget requests, many of the items gone over here and which Erich Bloch has addressed in some detail with considerable numbers.

Overall, we enthusiastically—I guess we could be more enthusiastic if the budget were bigger—but at least within certain limits we enthusiastically support the structure and the fact that the NSF budget is bigger than it might have been.

In our prepared statement you will find that we raised a few caution flags here and there. In the short time available, I would really, rather than take a quantitative number, just address two issues in a more subjective way.

I would like to emphasize two points. The first is that although our research and development enterprise is vigorous, it is really very fragile. Little breaks can turn out to be very big ones. For example, at the present time already, research support budgets of the Federal agencies, National Science Foundation, for example, are already so small that the choices for supporting research programs are not being made between first and second rate proposals at all. It is a matter of having a set of superb proposals often indistinguishable in their quality from among which some choices have to be made.

So the situation is a very thin one. And we are losing important research opportunities. And what may not be so apparent to people outside of the research enterprise is that there is a very strong kind of permanent damage that can be done.

The rate of progress is very rapid and there is very strong competition. Both of these things contribute to the vigor of the American scientific enterprise, but it has another problem, and that is that a person who is forced out of the research activities for even a year or two, has little or no chance of coming in to make major contributions again.

It is as though you have somebody on the telephone and you put them on hold while you continue a conversation and you come back later and you think they have understood it all. And they are never going to be able to catch up. It is a very difficult situation.

Research scientists rarely embark on independent careers until the age of 30. And it takes a long time to be trained and it is a very easy way to lose them. And I think we are losing some very good people now already at the low level of funds that are available.

How much do we lose in competitiveness? I think it is considerable. And also as Erich Bloch has pointed out, the research funding is inextricably intertwined with higher education and technical training. And when we lose people out of the active research area, we are really also damaging the educational enterprise with respect to teaching people at those levels.

I should say that this kind of, in connection with some of the discussion we had before, this kind of a problem is one of the things that I think is making the scientific or the academic situation a more difficult one to attract people into, simply because students who even after they have had a Ph.D., who see the difficulty, tend to go and do something else. It is not bad that they go to industry at all, but I think it is making a serious problem for the universities.

I would also comment on the fact that the institutions are fragile. And I won't go into that at all except to comment about the problems that the OMB proposed action on 821 made for everyone.

The other item I would like to address briefly is the importance of our investment in research and development, especially basic research, a theme which has come up repeatedly here. Why should we care if our research and development enterprise is weakened and shrinks by various ways? We lose the ability to tackle unexpected problems. AIDS is a terrific example of that. Ten years ago we wouldn't have been able to get anywhere near understanding the problem. Because of the work that was available because there were people in place, it was possible in a relatively short time to move ahead and begin to understand what the problem is. One can have examples in agriculture which are quite comparable to that.

Mostly what has happened in our country is we have changed from a technically based economy, a technically based industry. Thomas Edison could invent electric lights without knowing very much about electricity. Antibiotics could be discovered and used for medicine without understanding how they work.

We have really moved a great deal. Great inventors are still very important but we have really moved very much to a science-based technology in which the investment in research has to come first. Probably one of the best examples is biotechnology.

And the fact that West Germany and Japan are investing more than we are has already been alluded to. But in closing this part of the discussion, I am really reminded of a conversation I had about a year ago which puts some of this international problem, I think, pinpoints it very well.

A Chinese-American colleague of mine, who was a molecular biologist, is involved with the Government of Taiwan in building up a new biotechnology center, which they are setting up. And there are three American-Chinese who are helping their Chinese Government in this.

And he told me how much money they were putting in, I have forgotten exactly what it was, but it was a substantial amount for them. And I said: "Well, are they really committed to it?" He said: "Oh, yes. Why are they committed to it? Well, they recognize that the manufacturing that they have been doing is moving to Southeast Asia. And they are not going to be able to do that, so they have to try to get into the technology side."

My response was: "Oh, they think they are going to be the United States of the next generation?" And he said: "Oh, yes, that is probably right. And the Japanese are doing it already."

And so the problem that comes to us is what are we going to be in the next generation? And we don't really understand quite how to do it but having taken away our basic research capability certainly can't help that at all. Thank you very much.

Senator **Gorton**. Thank you, Doctor. Your entire written statement will be included in the record.

Could you give me your assessment of the National Science Foundation's progress in connection with people versus instruments versus facilities? Mr. Bloch spoke of that briefly.

Dr. **Bogorad**. Well, as a university professor, I am very much in the people business. And we are very much interested in training people and know that has to be done and nothing gets done without people. But the problem is that you also can't do any of the research if you don't have a place to put people that isn't up to date for them to work in or any space for them to work in.

And the universities, and I think particularly the private universities, are in a very difficult position with respect to that. And you can't work without having money to do research, which is very expensive. So I think there is a difficulty.

We can't train people and have them come to the end of that training period and say, that is great, you are trained but we don't have any money to support you in any research activities or we don't have any equipment for you to use.

So I am not sure that I could make that slicing quite as easy. I think they are so intertwined that we really have to consider the whole picture.

Senator GORTON. Thank you. You mentioned in your written statement your support for social and behavioral sciences. On a much more specific level, do you support the transfer by the provisions of the House bill of $3 million out of the Antarctic program into social sciences?

Dr. BOGORAD. First of all, I have to say I am here as a representative of the AAAS and we represent science very broadly, so it is not such an easy question for me to answer.

Senator GORTON. That is why it was asked.

Dr. BOGORAD. I should also say I am a biologist and the BBS includes biology, so that makes it even more difficult. It really comes to the issues that were being raised by Senator Gore; that is, that we are behind; that the advances in the social sciences are difficult to make; that the funding is behind and that we need some support there.

On the other hand, obviously the Arctic program is very important. So I am sorry to not be able to give you a sharper answer. And an answer that says we need both, of course, is not very adequate. And one has to make that decision.

Senator GORTON. My final question would be to ask you to comment on the state of negotiations between the academic community and OMB on limiting indirect costs?

Dr. BOGORAD. The state of negotiations is that the decision is put off until July 1, I think, with refusal to permit more comments. It is interesting to note David Packard, who is a member, the cochairman of that panel has taken up the battle on the side of the universities, pointing out that in that report which is being discussed today, that that is only one of a whole set of things and the OMB has conveniently selected to take that issue off.

The universities need all the help they can. And it is really a very important issue. Some universities stand too—first of all, it comes back to one of the things which is in that report which says that the Government ought to cover all of the costs of the research that it introduces.

Right now a lot of the equipment coming into the universities is on a cost sharing basis. You need a whole instrument; you get half from the NSF. You can't use half an instrument. If your university has some money, fine. Otherwise it is a problem. That certainly is not doing it. And one understands the budgetary problems.

If one now takes away some of the audited costs because these are not synthesized costs, these are real costs that somebody has agreed to, that kind of problem gets even worse because the reduction in support for students, the reduction in this kind of overhead, each of those things makes another problem for the universities and soon there is no money to do any of these things.

So even having some funds availabile to support science, which are on a matched basis, may not do any good if this goes on farther enough.

Senator **GORTON**. Thank you very much. Senator Rockefeller.

Dr. **BOGORAD**. If I may add one more thing. One of the discussions was why people don't go into universities? And part of Mr. Bloch's comments were that their salaries are not competitive.

And I was interested to see that one of the ways he plans to economize is to make that difference greater by reducing the contribution to academic salaries.

Senator **ROCKEFELLER**. How would you characterize the difference now and 10 years ago in terms of your students with respect to their training, their motivation and their aspirations?

Dr. **BOGORAD**. You are talking about graduate students or at all levels? I must say we personally have very highly motivated students. At the graduate level, I think the motivation is high. They work very hard. They are there day and night often. Somebody is there every night and somebody is there every day.

I think they are very highly motivated but I think they are somewhat depressed by the prospects of going into academic research, based on the difficulties of getting support for what they are doing. So I don't see any diminution when they come in. I see a little diminution of when they go out. And I hope it is not what I have done to them, but it is in part from there having looked around and seeing what the difficulty is.

So I don't think there is any change in the personality. But they are realistic about the prospects.

Senator **ROCKEFELLER**. How important is money, the salary differential in different fields, to them as opposed to the return on their education as compared with 10 years ago?

Dr **BOGORAD**. I don't think that really is making very much difference. It is making some difference but people who decide to go into the academic life anyway sort of say, well, I expect to make enough to live on but I really don't expect to get very rich.

And the difference between having enough to live on and getting very rich means a huge amount of money that you are not going to come near anyway. So I think that one other thing, of course, that makes that remarkable is the fact that these people as graduate students have been living on poverty level, have been supported at the poverty level of $6,000 or $7,000.

And it is remarkable that despite that, well maybe it is because of that the difference seems so great, that they are quite interested and willing to go out. So it would be better if they earned more but probably the differential between industrial and university salaries plus the research difficulties are the things that are making it more difficult to fill university positions.

Senator **ROCKEFELLER**. Is there an approximate level of debt that your average graduate student leaves with?

Dr. **Bogorad**. I am not sure. It is considerable. The undergraduates tend to leave with quite a lot. The graduate students do also leave with some level of debt but I am not sure what it is. We could probably get some numbers for you.

Senator **Rockefeller**. Double digit?

Dr. **Bogorad**. Double digit with three digits after that, sure.

Senator **Rockefeller**. Thank you.

Senator **Gorton**. Thank you very much, Doctor. We appreciate your being here.

[The statement follows:]

Statement of Dr. Lawrence Bogorad, President-Elect, American Association for the Advancement of Science

INTRODUCTION

Mr. Chairman and members of the committee, on behalf of the AAAS, I would like to thank you for the opportunity to submit a statement for your consideration.

I am the Maria Moors Cabot Professor of Biology at Harvard University, but I am presenting this statement in my capacity as President-elect of the American Association for the Advancement of Science (AAAS). Briefly, the AAAS is an umbrella-like organization whose members span virtually all fields of science and engineering. Affiliated with us are some 285 other scientific, engineering, technical and professional organizations with a total membership in the range of five million.

Within the past decade or so, we have become more and more involved in matters of national science and technology policy and the public understanding of science and technology through our publications, various special conferences, hearings such as this, and our annual meeting. This growing interest in national policy matters is, of course, indicated in the depth of our support for this Committee's work. Also, we have recently revised the organization of our flagship publication, *Science*, to reflect a greater emphasis on science policy areas.

ORGANIZATION OF STATEMENT

I would like to address several major topics based on our preliminary analysis of the President's FY 1987 Budget as submitted to the Congress. In the context of these major topics I will comment on specific aspects of the FY 1987 National Science Foundation Budget Request. I intend to address the following topics:

Policy Environment for Science and Technology; Overview of R&D: Federal and National—Including the Arrival of Gramm-Rudman-Hollings; International Science and Technology; Infrastructure Issues: Facilities, Equipment and Instrumentation; Management of Science and Technology.

In concluding, I will offer several suggestions and recommendations for the Committee's consideration.

POLICY ENVIRONMENT FOR SCIENCE AND TECHNOLOGY

American science and technology have earned great respect throughout the world. In fields such as health, agriculture, space, communications, and computers, the world's respect for American science- and engineering-based achievement borders on awe. This is a return on our long-term investment in people, institutions and facilities. Successive administrations and congresses have wisely seen that research is an investment in the future and they have made the investment.

Despite past achievements, perhaps the question might be raised, "In a 'bottom-line' sense, during a time of economic stringency such as the present, what difference would it make if we cut back for a time on our national commitment to science and technology to save money and reduce the responsibility of the federal government?" I would respond by saying, "While there are some things we could do which might be more foolish, there are not many." Why is this so?

Through most of our history as a people, our economic success was in substantial part predicated on an open-minded, pragmatic orientation to technological utilization of natural resources for the general well-being. Much of this was based on a common sense approach to imaginative craftmanship, as exemplified by many of our great inventors. But even by the Civil War, President Lincoln recognized that we would have to orient more toward fundamental research as a way of generating technological innovation.

Thus, over time, increasingly the new technologies central to economic progress and national defense—national security in a broad sense—came to depend upon advances in fundamental science as we invested in the future during the past half century.

Science and science-based technologies have become a pervasive part of human experience in the 20th century and the key to present and future well-being. Science is not a separate activity, remote from the lives of people—however arcane it may seem to be. To the contrary, it is bound up with everything we do which is central to modern living and much of its promise for the future, not only in a material sense but also in relation to social justice.

If we are seriously concerned with economic growth, productivity, innovation and equitable distribution of the resulting benefits, as we should be, then we must also be seriously concerned with the vigor of our scientific enterprise for we are really talking about the future of society. From this enterprise comes an increasing array of opportunities in every facet of human experience. Our food supply, our health, our global environment, our security, and our ability to make a living, to improve the quality of life and diminish human suffering—all depend increasingly on science-based activities.

AN OVERVIEW OF FEDERAL AND NATIONAL RESEARCH AND DEVELOPMENT LEVELS

In this section I will discuss briefly several important features and possible trends involving national and federal R&D, with special emphasis on the arrival of Gramm-Rudman-Hollings. Also, I will comment on the overall character of the NSF Budget Request for FY 1987.

The national total for research and development in 1985 reached nearly $109 billion—exceeding over $100 billion for the first time

It is estimated that the total amount invested in research and development in the United States in 1985 was in the range of $108.8 billion. The federal total comes in at about $51.7 billion (or 47 percent), while the non-federal component is estimated at $57.1 billion (or 53 percent). As Appendix 1 shows, the ratio has been essentially constant since 1980.

Appendix 1 also shows that total national R&D for 1986 is estimated to be in the vicinity of $118.6 billion. Another important point is that after a long plateau of little real growth since the mid-1960's, substantial growth began in the late 1970's (as shown in the constant dollar column).

It is also clear from an examination of Appendix 1 and other supporting data that the private sector is making significant investment in research and development as part of its various competitive strategies. But, the major focus is on applied and development activities in contrast to basic research.

The arrival of Gramm-Rudman-Hollings has so far had mixed effects on the aggregate levels of Federal R&D: A reduction in FY 1986 was made but the President has submitted the FY 1987 budget with substantial increases

While the overall federal budget clearly shows the influence of G-R-H, and the FY 86 R&D total ended up at about $2.54 billion lower than the appropriated amounts, the overall FY 1987 research and development level seems to be remarkably healthy. There are, however, various "symptoms" which seem to call for closer examination. For example, I would like to review with you the table below which shows a comparison of aggregate numbers for federal research and development, beginning with FY 1984. (The figures are for appropriations, i.e., budget authority.)

TOTAL FEDERAL RESEARCH AND DEVELOPMENT

[In billions of dollars]

	FY 84 appropriation	FY 85 appropriation	FY 86 appropriation	FY 86 G-R-H impact	FY 87 request
Total Federal R&D	$46.0	$51.7	$57.5	$54.7	$63.2
(Basic research)	($7.1)	($7.8)	($8.3)	($8.0)	($8.6)
Basic research (percent)	15.4	15.1	14.5	14.7	13.6
TOTAL FEDERAL R&D DIVIDED BETWEEN DEFENSE AND NONDEFENSE					
National Defense	$30.5	$34.7	$39.6	$37.6	$46.4
Nondefense	15.5	17.0	17.9	17.1	16.8

TOTAL FEDERAL RESEARCH AND DEVELOPMENT—Continued

[In billions of dollars]

	FY 84 appropriation	FY 85 appropriation	FY 86 appropriation	FY 86 G-R-H impact	FY 87 request
Defense percent of total R&D	66.3	72.0	68.9	68.8	73.4

A quick look at these numbers shows that the total amount for federal R&D has been increasing at a healthy clip. However, the numbers also vividly underscore NSF Director Bloch's repreated public declaration that the already small share of dollars allocated to basic research is steadily dropping, even though NSF's budget fared well in a difficult budget period.

I draw this letter trend to your attention in relation to my earlier comments about how very important it is that the basic research programs of the federal government be protected in the coming budgetary battles. And the National Science Foundation's programs are squarely in the middle of the strongest candidates for such protection and nurturing. Any cutbacks in the basic research area by the federal government will not be picked up by the private sector—as we have testified many times before, based on extensive review of the types of R&D that industry does support.

A more detailed look at the entire budget—although I will not review specific numbers today—shows that its dominant feature is the overwhelming emphasis on national security research and development. Since 1980, this element has risen from about 50 percent of federal R&D to over 73 percent in the FY 1987 budget request, and may well be on a rising trend. Other important themes in the overall budget appear to be as follows:

Overall, the National Science Foundation was one of the few civilian agencies which received a healthy increase, 8.4 percent. The increases were largely in the physical sciences, engineering, biotechnology, and advanced computational capabilities—much of which was couched in terms of improving our industrial competitiveness. Space was another area singled out for increases—although the shuttle disaster has raised considerable uncertainty about NASA's ultimate budget configuration.

There is a leveling off of resources allocated to agricultural, energy and environmental research and development—as well for the Agency for International Development, the Veterans Administration and various other smaller agencies.

Reductions are the order of the day for the Department of Transportation, Interior, and Commerce, and the National Institutes of Health, although the last word may not yet be in place on these cuts.

These trends or themes do not seem to be results of G-R-H influences; rather they reflect the continuation of Administration policies in place for the past five years. Some of the reductions may well support deficit reduction objectives, but it would not appear as though this was the primary motivation, this year.

Future effects of G-R-H deficit reduction pressures are likely to be significant for R&D

However, as we attempt to peer ahead—along with you—it seems reasonable to forecast that the deficit reduction trend—with or without G-R-H in whatever form it emerges from the Supreme Court review—is likely to remain a potent political force. Among the resulting effects it is quite possible that further pressures will be placed on so-called discretionary areas such as civilian R&D. Just as likely, we would guess that national defense R&D will be subject to the same kind of pressures.

In short, in the outyears of 1988–1991 it is quite conceivable that we might experience a drastic paring down of our national R&D capabilities—including levels of research, production of scientists and engineers, and modernization of our research facilities, equipment and instrumentation.

Numerous concerns arise from this scenario; included is the basic problem of how we can preserve crucial elements of our scientific and technological enterprise and avoid foregoing or delaying follow-through on important opportunities. Finally, as I discussed earlier, there is the vital task of maintaining and investing in—for the long pull—a healthy basic research establishment, even if it becomes necessary to cut back on other parts of research and development.

The particularly distinctive responsibility of the federal government is in basic research. In the AAAS' effort to keep in touch with corporate research and with the foundation world, we see clearly that both the profit and non-profit private sector has only a modest contribution to make to basic research. So it is a matter of profound significance that we maintain the base on which we build the rest of our technical achievements and the application of those achievements.

While I am sure you will be presented with many examples of deficit reduction impacts, I think it is important to identify a problem which otherwise might be lost in the "noise level." I acknowledge that this is not your legislative concern; however, changes being discussed in postal rate policies could lead to substantial cost increases for distribution of scientific and technical journals—the lifeblood of scientific communication. It is feared that such changes, if they come to pass, could have a chilling effect on many precariously financed journals, particularly in smaller or emerging fields. Substantial additional direct funds would need to be added to research budgets to offset the enormous deleterious effect of such increases—this is a set of choices to be made in the Congress.

Effects of G-R-H on higher education will be severe: Since science, math and engineering education are integral parts of our scientific and technological enterprise in the United States, there are reasons to be concerned

We want to put the AAAS' views on education on record. The FY 1987 budget for higher education, at $6.7 billion, is 23 percent below the FY 1986 amount of $8.7 billion. And while the various programs deal with a broad variety of purposes, science, math and engineering education will be among the fields hit hard by the reductions. I will come back later to several specific comments on NSF's program and its education plans.

We have been coming before you regularly with our concerns about science, math and engineering education. Despite progress on a number of fronts, the looming impacts of G-R-H are reasons for serious alarm. The litany of problems has been well-documented in report after report and study after study, in recent years.

There is very little science instruction in elementary schools.

At the secondary levels too many students are unchallenged; there is a grave and worsening shortage of well qualified science and mathematics teachers; the curriculum lacks coherence and needs overhauling; and computer literacy is a major concern.

At the present time, undergraduate science and education receives almost no support.

There is a low level of research effort on teaching and learning; resources are limited for the development of classroom materials; teacher training in mathematics and science throughout the precollege level in woefully inadequate.

During the past few years the nation has experienced a rediscovery of education, especially in the linkage between science and technology education and the economy. Much is happening at state and local levels under the influence of forward-looking governors and local officials, but it would be a grave mistake to use such actions as the basis for the federal government to step aside from its own special responsibilities. Too much is at stake. It is a tremendous challenge; and the federal government must be an active participant and leader in finding ways to link the "science-rich" sectors (the universities, corporate labs and national labs) with the "science-poor" sectors in the elementary and secondary schools.

We may be at an historic moment in education with a challenge and opportunity comparable to the period of the Civil War when the land-grant colleges were established. Historically, education support has always been tied to other objectives, such as national security (Sputnik) or social justice (Great Society). Now, the emerging tie is to the scientific and technological needs of the new economy. With this emergence comes the urgent need to raise the status of education as a profession.

In thinking about the basic education issues, I think these are among the more important questions:

How can we give all our children, regardless of social background, a good opportunity to participate in the modern technical world?

What constitutes a decent minimum of literacy in science and technology that should be a part of everyone's educational heritage?

Given the rapidity of socio-technical change, how can we make lifelong learning a reality so that people can adjust their knowledge and skill to technological change?

Since educational institutions will more than ever be preparing people for unpredictable circumstances, how can they prepare for change itself?

How can we broaden the spectrum of the sciences to include the full range of life sciences and behavioral sciences so that modern education will become increasingly informative with respect to human experience.

How can the educational system foster a scientific attitude useful both in problem solving throughout society and in relating scientific principles to the major issues on which an informed citizenry must decide?

How can we achieve an informed world-wide perspective in an era of profound global interdependence?

Such questions and the need to undertake systematic inquiry into them are founded in our strong belief that a fundamental transformation of our society and our economy is occurring as a result of the pervasive influences of science and technology. We believe there is the need for widespread and deep educational improvement to cope with accelerating change and that the current momentum—particularly in the states—suggests a readiness for action.

This set of problems is far too complex to be dealt with using simplistic nostrums such as "education is a local problem in our system of government." Of course, local control of education is at the core of our system; no serious-minded person even questions this premise. And, yes, far larger proportions of the total cost of education are borne at state and local levels. But federal money, experimental programs, and research activities provide highly leveraged capabilities that are difficult or inefficient to replicate at state levels. The massive, complex effort required in science education calls for national attention, stimulation, and leadership. The National Science Foundation is a good place to exercise this leadership but we think the Executive Office of the President could and should also play an important role.

The challenge is to develop and carry out an effective mix of federal, state and local educational activities to cope with the transformation I described a moment ago. I am reminded of an old anecdote of H.L. Mencken's; he said: "For every complex problem, there is always a simple answer—and it is always wrong." We need to work at meeting the real challenge.

NSF budget request in science and engineering education is something of a disappointment: there is too little progress, too slowly

Given the overall favorable treatment for the NSF budget, and the knowledge that Director Bloch and the National Science Board are serious in their intentions to improve the NSF's Science and Engineering Education program, we are reluctant to come down too hard in appraising the education budget and what lies behind it.

Nevertheless, we have concluded that, taking into account the importance of the overall national educational challenge discussed above, it is necessary o observe that there has been too little progress, too slowly accompanied. It is little short of astonishing to realize that a study to prepare a long-range plan, authorized and directed by the Congress in 1984 is just now getting underway with a target completion date of eighteen months from now.

Surely, it is not a matter of a shortage of reports and studies. I have already mentioned the plethora of such activities, including the excellent work of the National Science Board itself. We do hope the Subcommittee will exercise its oversight role in following the new study closely. In the meantime, we would like to offer several suggestions for the evolution of a national education program, largely under the auspices of the NSF.

There should be a balanced program of support for science, mathematics and engineering education. Our system requires strenghtening from the bottom to the top, i.e. from the precollege level, through undergraduate to graduate to post-doctoral levels. The specific needs at each of the levels has been thoroughly documented.

Support should be balanced with regard to the functional activities undertaken—research on teaching and learning; development of supporting materials; use of informal, out of school, approaches based in a variety of places such as museums; and training of teachers who are qualified to provide sound instruction throughout the precollege level.

A strategic plan must be developed which is based on a reasonable degree of stability and growth commensurate with the magnitude of the problems previosuly described. The kinds of funds required have already been partially identified in the Board's own Commission Report on Precollege Education in Mathematics, Science and Technology.

Finally, it seems logical that the National Science Foundation should provide the management focus on a national program of the kind we are discussing.

INTERNATIONAL SCIENCE AND TECHNOLOGY

Investment in R&D is growing among our international partners and competitors

In earlier appearances AAAS witnesses have repeatedly focused on the international dimension of science and technology, both in terms of the connection to international economic competitiveness and to international cooperation, particularly in science matters.

As a brief update, Appendices 2 and 3 to my statement show the allocation of national resources to investments in research and development by a number of key nations: France, West Germany, Japan, the United Kingdom and the USSR. As a summary point, each of the nations—except the United Kingdom—continues to allocate an increasing percentage of is Gross National Product to research and development—particularly in civilian-related areas.

The intensity of the international economic competitive environment is directly related to national investment in science and technology. A salient point is that our own national investment in civilian R&D has essentially leveled off while the Japanese ratio continues to increase (Appendix 3). Any decisions to reduce that investment must recognize the consequences.

The AAAS applauds and strongly supports current studies by the National Science Board and the Foundation itself in exploring ways the NSF might serve the national interest through its activities in international science and engineering

In supporting the Science Board's Committee on International Science, the AAAS endorses enthusiastically a recommendation of the Committee that the NSF assume a leadership role in planning and implementing one or more major global initiatives, in which other U.S. and foreign organizations could participate. For example, through our Consortium of Affiliates for International Programs we have been consulting widely with others in the scientific and engineering community to develop a list of five to ten candidate global initiative programs. From such a list it is hoped that a suitable activity or activities might be mounted.

A potential candidate has been identified in a special National Academy of Sciences Report as an "International Geosphere-Biosphere Program [IGBP]" which might be conducted under the auspices of the International Council of Scientific Unions [ICSU]. While it would seem appropriate for the NSF to have a leading role, an IGBP should be truly international, for the concerns are those of the entire planet. Considerations of access alone would require the participation of scientists and technicians from both advanced and developing countries representing all parts of the world. Proposed study areas would include:

The recovery of the past history of environmental change; changes in the current physical environment; global changes in the biosphere; global biogeochemical cycles; and the global hydrologic cycle.

It is encouraging that the NSF budget includes increased emphasis on the global geosciences through a series of interrelated research efforts treating the earth as an integrated system of physical, chemical, and biological processes. However, while other U.S. agencies were mentioned as participating, there was no indication that the initiative was "international" in the sense called for by the IGBP concept.

We think close attention should be given to this dimension of the emerging geosciences activities at the NSF. More important, we hope that this Committee will carefully consider how best to use its influence and prestige for bringing the IGBP into being. It could be an achievement of unparalleled importance in the history of human cooperation. It can provide information that we and other countries need but can be obtained only by our all working together.

New perspectives are required on developing coherent strategies for carrying out international cooperation—including "Big Science"

Here I must acknowledge and agree with a set of remarks presented by House Science and Technology Committee Chairman Don Fuqua at a "Technology Development" Conference in Bonn, West Germany, late in 1984. His thoughtful and provocative comments have probably not received that attention they deserved. His proposition that international cooperation in science and technology must be given greater priority is sound, and I agree wholeheartedly with his statement that the "time has come for it also to become a routine international exercise among nations."

In getting down to the really "hard stuff," Mr. Fuqua goes past the conventional rhetoric that international cooperation is a great goal. He raises some past "unthinkables," such as the necessity of giving up on a degree of nationalism in exchange for real collaboration on projects and research facilities, especially those connected with "big science." There is no doubt whatsoever in my mind that no nation will be able to afford to "go it alone" in building the coming generations of major facilities and projects of a global nature such as the IGBP discussed earlier.

INFRASTRUCTURE ISSUES

The research facilities problem remains critical at universities: Aging deteriorating, and terribly out of date

Much has been said to you in the past about this and I am aware of your concerns, so I will not dwell on this sad story today. I would only say that things are just as bad and getting worse. For the record, we would like to note our strong support for H.R. 2823, "The University Research Facilities Revitalization Act of 1985," and hope there will be some forward movement this year.

Even if the G-R-H climate does not permit the allocation of any additional amounts of money this year, it would be quite valuable for the problem to be examined thoroughly and a plan of action devised for such time as when funds might become available. We understand that an NSF report based on last July's meeting at the National Academy of Sciences will be available soon.

The prospects for progress in coping with research equipment and instrumentation problems seem brighter than those for facilities

We strongly support the actions taken by Mr. Bloch in increasing the total NSF allocation for instrumentation and equipment from $223 million in FY 1986 to $260 million in FY 1987. We agree with him that modern research requires state-of-the-art instrumentation and equipment. While the overall requirement remains huge—in the billions—the FY 1987 decision certainly represents some modest progress. We especially appreciate the modest increase for the undergraduate equipment program; we must not forget the entire range of education as I discussed earlier.

MANAGEMENT OF RESEARCH AND DEVELOPMENT ISSUES

There are several areas of concern and questions related to the management of federal research and development programs which we would like to put on the table. Among these are peer review versus "earmarking," indirect costs and the balance of research grants between individual investigators and centers.

There is growing controversy about the manner in which an increasing number of large research grants and facilities bypass peer review or even regular congressional review procedures

There is not time today to discuss our concerns in any detail; however, the trends are sufficiently disturbing to warrant bringing up the subject. The concept of peer review of science is a central characteristic of the American system and it is generally acknowledged that this approach accounts for much of the strength of American science. It is with dismay that many of us observe what seems to be increasing attempts—many of them successful—to bypass regular peer review processes during the budget allocation proceedings in Congress, or even the Committee-review system itself. Two recent examples illustrate the point I am making:

In the hectic atmosphere surrounding the windup of its 1985 Session, Congress "earmarked" special research grants for ten universities in the Defense Department's R&D program. The Conference Report on H.J. Resolution 465—the continuing appropriations for FY 1986—included the ten grants, none of which had been through even the Congressional committee review system. By the end of January, only one university, Cornell, had turned down its $10 million allotment of the total $65.5 million package. Ironically, Cornell had applied through normal Defense channels and had not sought the special political assistance given to it, much to its credit.

A package of amendments to the Higher Education Act (H.R. 3700) contained an array of specially "earmarked" facility authorizations for a number of universities. Regrettably, an amendment to substitute the "earmarking" with a method of distributing such funds competitively was defeated.

It is not that we lack understanding or appreciation of the geographical distribution question for R&D grants, contracts and facilities; my entire statement for you today rests on the premise of the close connection between advances in science and technology with economic and social growth. We are fully sympathetic with the near sense of desperation about aging or absent research facilities at many universities, and the desire to stimulate economic development.

The funds allocated by "earmarking" could very likely have been used more effectively if they had been pooled and their allocation channelled through a systematic application-review apparatus than through non-comparative, isolated, tacked-on appropriations. There is no question that more new facilities for research and training are needed at many institutions to maintain the vigor of our education and research enterprise. There is a serious question as to how that need should be met—through an overall appropriation from which grants can be disbursed or by "earmarking." On the whole, the U.S. academic-scientific research and training community has been willing to take the responsibility for making its own hard choices in an open competitive way by allocating funds made available by the federal government through the peer review. That is the real nature of the peer review system. We believe that it deserves and needs the support of the Congress.

Our urgent request to the Committee is that this general topic be placed on your oversight agenda. Your forum can provide an effective place and set of circumstances for addressing these issues, as you have in the past.

Reports of OMB intentions to impose uniform caps on indirect costs of federally assisted research grants call for caution

Again, this is a topic which could tie us up in discussion for days. Indeed, there are not many subjects which have been around longer in the world of federal support for research and development. But without going into the specifics I would only wish to state the concern of the AAAS that such moves not be taken without timely notice, discussion and adequate transition periods. There are many complexities and contending interests in this area, not only between universities and the federal government but also within universities themselves.

The balance of the research investment—grant to individual investigators versus grants to centers

We have seen enormous contributions come from individuals, individually directed small laboratory groups, and concerted efforts by interdisciplinary groups. The examples range from the lone investigator in a university, government or industrial laboratory making a seminal discovery through to large joint efforts like the Manhattan Project. Director Bloch has been making the compelling argument that this may be the time to shift some resources into group efforts in research centers. In fact, the NSF has funded a number of Multidisciplinary Engineering Research centers and there are proposals to do the same in other fields. The argument, in part, is that there are many current research problems which can benefit from an integrated effort carried out by a group of people with different disciplinary interests.

The AAAS, more than any other scientific society or association in America because of its own interdisciplinary nature, can appreciate Director Bloch's point of view. It is an important and interesting experiment. It is hard to imagine that it will not make a difference.

Besides its most direct results—in effect advancing scientific progress—it will require universities to rethink some of their structural features in order to open ways for faculty members to cooperate. In addition, it will probably recast the demand for facilities that will have to be met through some financing mechanism that may not now exist; and it will require peer review groups as well as the NSF and the sponsoring institutions to think hard and carefully about ways of avoiding attention to weak spots that can be carried along in larger programs.

All of these are, in fact, virtues of trying to set up some number of basic research centers. But one of the great strengths of American science and the structure of our research enterprise has been its nonhierarchial, entrepreneurial nature. The democratic atmoshpere of Amercian universities and their laboratories has been an important element in driving us to explore new directions. Each assistant professor in a university is an individual entrepreneur who can seek financial support for a specific project, succeed or fail on his or her own, and go on to take a more permanent place or fall by the wayside. This is repeated over and over again with each new appointment of a young person to a position in a research university.

To some extent—but perhaps a bit less—the same thing occurs in some national laboratories. It occurs to a lesser extent in larger integrated organized groups where the evaluation is often not so detailed for a peer reviewed proposal. An important question that will have to be faced is how much money should be put into research centers, how much into research grants to individuals? And how is all this to be balanced in a time of static, if not contracting, overall research support?

The questions of research centers versus individual grants always brings to mind the problem of research funding stability. Research grants awarded by the National Science Foundation, at least in biology, the field I know best, are commonly awarded for two or three years' duration. This pattern pushes research towards short quick strokes. The best science is addressed at specific answerable questions (although a finding stumbled on along the way may turn out to be very important). But sometimes very important questions cannot be answered in a short time even though the plan is clear and focused. It may be that because of their size alone—and the attendant difficulty of winding down—that research centers may open the way to addressing some of these questions that require more time.

ADDITIONAL NSF BUDGET COMMENTS

While I have discussed previously several aspects of the FY 1987 NSF Budget Request, there are a few more specific comments to offer.

Overall, the budget is a good one, considering the times. Further, I would like to acknowledge the NSF's—and particularly Director Bloch's—role in the continuing attention and progress on programs for encouraging and supporting scientific and engineering study and careers for women, the disabled and minorities. As an NSF report released at the end of January shows, there have been substantial gains in science and engineering employment for women and minorities since the mid-1970's. Given this success, which can be attributed in part to NSF's pioneering role, we would urge a continuing focus for such areas as:

(1) Being cautious about ill advised or premature mainstreaming of minority-focused programs;

(2) Building a cadre of minority, women and disabled students in science and engineering by early involvement in research;

(3) Special training for various NSF program officers as the minority-women-disabled programs become mainstreamed.

We remain somewhat puzzled by the status of the social and behavioral sciences research. For example, even in such important topics as industrial productivity and innovation, research findings from the social and behavioral sciences frequently are of as great or greater consequences than those from the physical sciences and engineering. We regret that OMB and the NSF do not seem to share this point of view.

We remain concerned about the marginal attention given to the behavioral and social sciences. For example, no special or distinctive statement regarding these vital fields is made in the NSF Budget Summary for FY 1987. I focus on this because these sciences are just beginning to recover from the budgetary beating they took a few years ago. They are crucial to understanding serious problems in our changing economy, its relation to technological advances, and its demands on education for a transforming workforce. Another crucial problem is conflict resolution in a world full of prejudice, hatred, and violence. Moreover, the past decade has seen a rousing awakening to the links between health and behavior—e.g., smoking, alcohol abuse, a variety of damaging drugs, and several major risk factors for heart disease, stroke and cancer.

These three areas of great concern—the economy, conflict resolution, and health-behavior links—illustrate the importance of the behavioral sciences for our future well-being.

I am pleased that the Congress chose to respond favorably to the many concerns expressed last year about the little program on Ethics and Values in Science and Technology [EVIST]. It is also encouraging that Director Bloch has decide to continue sponsoring research in this field. Having said this, I have a small cautionary note: as small programs get distributed throughout the array of NSF directorates and programs, there is the very real risk of a loss of focus. We hope this Subcommittee will continue to monitor this important little area where so many important interdisciplinary studies are done.

CONCLUDING REMARKS

Overall, American science and technology is in good health; we invest large amounts of money in research and development and we get good value for it. But the scale of our expenditures must be compared to our needs, to the size of our economy, and above all, to the relative investments by competitors in civilian and defense related areas. Our capacity to do excellent work is much greater than our resources in many fields. There are ample reasons for caution in cutting back or restraining too severely R&D growth in the G-R-H environment.

There is special reason for alarm in the realm of basic research. Although the American basic research enterprise is strong, it is also very fragile. R&D is one of the multi-filamented cables that pulls the American economy and helps to compete in the internatonal industrial competition. To pull a heavier load faster, we need a stronger cable. We cannot afford to break fibers in the R&D cable at this time. Once broken, a fiber does not wait in place to be repaired. Under stress, the cable stretches and the gap in the snapped single fiber gets bigger and bigger and harder and harder to repair.

The specific budget of the NSF for FY 1987 warrants your strong support. But beyond this budget and this year, and despite the looming G-R-H pressures, I would argue for some slowing down of large development programs if that becomes necessary to maintain healthy, steady but modest building of the great research-sponsoring agencies of the federal government such as the NSF, the National Institutes of Health, and, yes, the Defense Department and the Department of Energy.

In making judgments on such support, science policy should place special emphasis on basic research across the entire spectrum of the sciences. It is from such research that the companies and industries of the 21st Century will arise. In this context, we must foster the continuing interplay of basic and applied sciences so that each may stimulate the other. Special attention must also be devoted to creating and encouraging an environment for cooperation among government laboratories, universities, and industry.

We strongly support the Administration's drive to provide incentives for industry to strengthen research and development across the board, not only in the obviously high-tech industries. Building a bipartisan consensus for support in this area is a high priority.

Strengthening basic research in the field of agriculture is important to our well-being, our health, and our role in the world. Our big problem here is that we have done so well that complacency can become a danger. (Indeed, the same could be said for health research.) But there are issues that deserve our sustained attention: massive soil erosion, looming water shortages and contamination, decrease in the genetic variability of plant life, and the uncertain role of the new biotechnologies with regard to agriculture.

The oil glut is temporary. The basic facts have not changed. The long-run supply is seriously limited and many of the sources are politically volatile. We cannot set aside research on conservation and alternative energy sources. We must take a long view of the fact that the United States is the most energy-intensive nation in the world today and that others are moving rapidly in his direction.

We must undertake and support a variety of measures, including stronger support for education, to provide distinctive opportunities for young people to participate effectively in this emerging scientific and technological age. These opportunities should be available regardless of race, gender, or religion.

Finally, and this is nothing new to this Committee, it is increasingly important that eventually we face the need for better governmental and private mechanisms in science policy formulation. We must do a better job of analyzing and appraising the various options and policy measures embedded in just the short list of issues I have reviewed—and it is by no means complete. This general need becomes even more acute as we contemplate the growing international and global dimensions which I have discussed only briefly in my statement.

MAJOR RECOMMENDATIONS

1. Provide strong support for the NSF Budget as proposed. While our differences with the NSF on education are significant, they do not translate into specific budget comments this year. We would hope that the Committee will use its good offices to speed up the planning process at NSF. For the longer term, a growing role for the NSF in science education will be crucial.
2. Focus attention on the newly emerging dimensions of international science and technology-ranging from a pronounced role for the NSF to the considerations for establishing one or more major global cooperative efforts. The International Geosphere-Biosphere Program (IGBP) seems to be a likely candidate.
3. Give special attention in international science and technology to more intensive examination of more effective ways to collaborate on research projects and facilities.
4. Carefully monitor the NSF commitment to the behavioral and social sciences.
5. Consider peer review as the internal priority-setting apparatus that it is and recognize that the several trends of "earmarking" funds discussed briefly in my statement deprives the nation the use of this informed mechanism. Still, the Congress must recognize the national needs for research and training facilities.
6. Consider a number of the policy issues noted above—particularly that dealing with the new institutional ways to accomplish the required policy analysis more effectively.
7. Finally, in the turbulent times ahead as you deal with the political ramifications of deficit reduction, please consider the investment character of research and development—particularly, basic research and that even small breaks take a long time to heal.

APPENDIX 1.—TRENDS IN FEDERAL AND NON-FEDERAL R&D OUTLAYS: 1953 AND 1960–86

[Percents]

Year	Federal				Non-Federal	Total National (constant) dollars (1982)	Total National (current) dollars
	Total	Defense related	Space related	Civilian related			
1953	54	48	1	5	46	$19,744	$5,124
1960	65	52	3	9	35	43,648	13,523
1961	65	50	6	9	35	45,764	14,316
1962	64	48	7	9	36	48,176	15,394
1963	66	41	14	11	34	52,585	17,059
1964	66	37	19	9	34	57,202	18,854
1965	65	33	21	11	35	59,351	20,044
1966	64	33	19	12	36	62,589	21,846
1967	62	35	14	13	38	64,406	23,146
1968	61	35	13	13	39	65,458	24,605
1969	58	34	11	13	42	64,672	25,631
1970	57	33	10	14	43	62,405	26,134
1971	56	32	9	15	44	60,385	26,676
1972	56	32	9	15	44	61,414	28,477
1973	53	30	8	15	47	62,427	30,718
1974	51	27	8	16	49	61,467	32,864
1975	51	26	8	17	49	59,885	35,213
1976	51	26	8	17	49	62,134	39,018
1977	50	25	8	17	50	63,653	42,783
1978	50	24	7	19	50	66,769	48,129
1979	49	23	7	19	51	70,077	54,933
1980	47	22	7	18	53	73,235	62,593
1981	46	23	7	16	54	76,610	71,840
1982	46	25	7	14	54	79,328	79,328
1983 estimate	47	27	7	13	53	83,862	87,178
1984 estimate	47	29	6	12	53	89,937	97,275
1985 estimate	47	30	6	11	53	97,283	108,800
1986 estimate	47	30	7	10	53	102,504	118,600

Note: Detail may not add to 100 percent because of rounding.

Source: National Science Foundation.

APPENDIX 2.—NATIONAL EXPENDITURES FOR PERFORMANCE OF R&D AS PERCENT OF GROSS NATIONAL PROUDCT (GNP) BY COUNTRY: 1961–86

	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.
Year:						
1961	1.37	NA	1.39	2.47	2.68	NA
1962	1.47	1.25	1.47	NA	2.68	2.64
1963	1.55	1.41	1.44	NA	2.81	2.80
1964	1.81	1.57	1.48	2.30	2.90	2.87
1965	2.00	1.72	1.52	NA	2.84	2.85
1966	2.07	1.81	1.46	2.32	2.83	2.88
1967	2.12	1.96	1.52	2.30	2.84	2.91
1968	2.08	1.98	1.60	2.26	2.76	NA
1969	1.93	1.82	1.64	2.27	2.66	3.03
1970	1.92	2.06	1.85	NA	2.57	3.28
1971	1.90	2.18	1.85	NA	2.42	3.46
1972	1.90	2.20	1.86	2.11	2.40	3.71
1973	1.77	2.09	1.90	NA	2.26	3.81
1974	1.79	2.13	1.97	NA	2.23	3.74
1975	1.80	2.22	1.96	2.19	2.20	3.78
1976	1.78	2.15	1.95	NA	2.19	3.61
1977	1.76	2.14	1.93	NA	2.15	3.54
1978	1.76	2.24	2.00	2.24	2.14	3.54
1979	1.81	2.40	2.09	NA	2.19	3.59

APPENDIX 2.—NATIONAL EXPENDITURES FOR PERFORMANCE OF R&D AS PERCENT OF GROSS NATIONAL PROUDCT (GNP) BY COUNTRY: 1961–86—Continued

	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.
1980	1.84	2.42	2.22	NA	2.29	3.76
1981	2.01	2.49	2.38	2.41	2.35	3.75
1982	2.10	2.58	2.47	NA	2.51	3.68
1983	2.15	2.52	2.61	2.24	2.56	3.82
1984 preliminary	2.24	2.52	2.60	NA	2.58	3.95
1985 estimate	2.27	2.61	NA	NA	2.72	NA
1986 estimate	NA	NA	NA	NA	2.76	NA

NA—Not available.

Source: National Science Foundation, Organization for Economic Cooperation and national country sources.

APPENDIX 3.—ESTIMATED RATIO OF CIVILIAN R&D EXPENDITURES [1] TO GROSS NATIONAL PRODUCT (GNP) FOR SELECTED COUNTRIES: 1967–85

	France	West Germany	Japan	United Kingdom	United States
Year:					
1967	NA	NA	1.51	NA	1.88
1968	NA	1.80	1.59	NA	1.83
1969	NA	1.87	1.63	NA	1.79
1970	NA	2.01	1.79	NA	1.76
1971	1.5	2.0	1.8	NA	1.6
1972	1.5	2.1	1.8	1.5	1.6
1973	1.4	2.0	1.9	NA	1.6
1974	1.4	2.0	2.0	NA	1.6
1975	1.5	2.1	1.9	1.4	1.6
1976	1.4	2.0	1.9	NA	1.6
1977	1.4	2.0	1.9	NA	1.6
1978	1.4	2.1	2.0	1.5	1.6
1979	1.4	2.3	2.1	NA	1.7
1980	1.4	2.3	2.2	NA	1.8
1981	1.5	2.4	2.4	1.7	1.8
1982	1.6	2.5	2.5	NA	1.9
1983	1.7	2.4	2.6	1.6	1.9
1984 estimate	1.8	2.4	2.6	NA	1.8
1985 estimate	NA	2.5	NA	NA	1.9

[1] National R&D expenditures, excluding Government funds for defense.
NA = Not available.

Sources: National Science Foundation and Organization for Economic Cooperation and Development.

Dr. Gray, Dr. Kleppner, and Dr. Schmidt are next. The chairman regrets that he is going to have to leave promptly at noon. Senator Rockefeller will be able to stay for an additional period.

Because of that, and because Dr. Kleppner is the one who comes from a distance, I will hear from him first and ask him one or two questions and then go on to the others. Would you proceed?

And in the case of each of you, your written statements will be included in the record.

STATEMENT OF DR. DANIEL KLEPPNER, PROFESSOR OF PHYSICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY; DR. HARRY G. GRAY, COMMITTEE TO SURVEY OPPORTUNITIES IN THE CHEMICAL SCIENCES, NATIONAL RESEARCH COUNCIL; AND DR. MAARTEN SCHMIDT, PRESIDENT, AMERICAN ASTRONOMICAL SOCIETY

Dr. **Kleppner**. Thank you very much for inviting me to appear before the committee to talk about the physics survey and its implications for the National Science Foundation.

I respectfully request that my written comments be put into the record. The physics survey is much too large to even start talking about in 5 minutes. Instead, I would like to reflect on some of the issues which have been raised this morning because those issues are absolutely central in the physics survey.

In looking to the future of physics in the United States, the situation can hardly be called healthy because of serious problems in science education at every level. I am sure you are all familiar with the problems of primary and secondary education. The full drama of these problems came home to me recently during a visit to a physics department which, like many physics departments, had many foreign graduate students, including a good number of excellent Chinese students. My host explained a situation in which resentment was building on the part of the Americans against the Chinese: the Chinese had such high standards, that they were making life difficult for the Americans.

What this meant to me is that with respect to education, discipline and motivation, these Chinese students were ahead of our United States students. To me this represents the legacy of decades of neglect of primary and secondary science education. It reflects, Senator Rockefeller, the issues that you brought up about the cultural roots of the problems in education that we face.

Inadequate science education is a severe problem because of its deep cultural origins, but we can do something about it. In particular, the National Science Foundation should play an important role in stimulating primary and secondary science education.

The major problem that I would like to talk about however, is at the graduate level. This is the problem of university-based research, an issue which is absolutely central in the physics survey.

The difficulty of carrying forward university-based research in physics is so great that university careers have become demonstrably less attractive than formerly. I think that we are starting to see the first results of this situation.

I did a private survey last spring of university departments to ask whether they had enough candidates for faculty positions which were open. Most people believe that there is a long waiting line for university faculty positions. It turns out, however, that in experimental solid state physics there is a shortage of candidates for these positions. The shortage was inescapable. Of 19 universities that responded, 12 specifically addressed this issue. They could not fill the positions.

To me this shows the legacy of neglect of university research for many years; the careers have become so unattractive that in at least one area we cannot attract first rate people to the universities.

If we cannot fill the university positions with first rate people, eventually we will have to fill them with second rate people. That would constitute a terrible decline. I think we are on the threshold of such a decline. If we cannot provide adequate support to allow young scientists to achieve fulfilling careers in universities, they will look elsewhere. We are starting to see that now.

I would also like to mention that the number of foreign graduate students in physics right now is over 40 percent. Furthermore, over half of the postdoctoral researchers in this country are from abroad. We are heavily dependent on foreign scientific manpower in physics in the United States.

This is an obvious cause for concern, particularly because most of these foreign scientists are ineligible to participate in DOD research. The DOD doesn't seem concerned about the supply of scientists and the needs for basic research, but it is going to face the consequences of this shortage more quickly than anyone else.

These are just two of the issues of the physics survey, but they reinforce the issues brought up earlier by Dr. Schmitt and Mr. Bloch. I think they have eloquently stated the situation. And I don't think that anything they have said is of an exageration. There is real reason to worry about the future. Thank you.

[The statement follows:]

STATEMENT OF DR. DANIEL KLEPPNER ON THE PHYSICS SURVEY AND THE ROLE OF THE NATIONAL SCIENCE FOUNDATION

My name is Daniel Kleppner and I am a professor of physics at the Massachusetts Institute of Technology. For the past three years I have served on the Physics Survey Committee of the National Research Council, assisting in the preparation of the Physics Survey *Physics Through the 1990s* that has recently been published by the National Academy Press. The Survey Committee was charged to examine physics in the Nation and the opportunities and needs for the future. The National Science Foundation plays the major role in key issues of our findings, and it is these issues that I would like to briefly summarize for you.

We are living in one of the most exciting periods in the history of physics. The subfield reports that constitute much of the Physics Survey describe advances in cosmology, particle physics, plasma, nuclear and condensed matter physics, and atomic, molecular and optical physics. Many of these advances are starting to become familiar to the public: the dramatic scenario of the birth of the universe, the magic of laser light, new wonder technologies for medicine such as magnetic resonance imaging, the information revolution due to electronics and communications. Other advances are so new that physicists themselves cannot yet fully appreciate their implications: the creation of materials on an atom-by-atom basis, the ability to take "snapshots" of molecules in a millionth of a billionth of a second—a time so short that their motion can be stopped dead in the middle of a chemical reaction, the dramatic progress toward understanding the fundamental unity that physicists believe underlies all of the forces of Nature.

The Survey summarizes these advances in the following words. "Viewed collectively, these discoveries in physics are among the greatest achievements of our time. The impact of physics extends far beyond the satisfaction of man's desire to understand nature, for physics is a central discipline that contributes theoretical concepts and experimental techniques to all the other natural sciences, to technology and to medicine. Physics is a vital component of such national programs as energy development, environmental improvement, and security. Discoveries in physics have generated entire industries such as microelectronics and optical technology. By helping the nation to maintain technological leadership, physics constitutes a driving force in our economy."

In looking to the future, however, serious problems are evident. The National Science Foundation must play a central role in dealing with these problems. Conspicuous among these is that the number of U.S. graduate students is declining, the decrease being mirrored by a steady increase in foreign students. At present, over forty percent of incoming graduate students in physics are foreign. Furthermore, more than half of our postdoctoral researchers are foreign. For the first time since World War II the United States is dependent on foreign scientific manpower. That we are no longer able to produce enough U.S. physicists for our basic national needs is an obvious cause for concern.

Another serious problem is the need to replace our aging university and college faculties in the next decade. In 1970 the median age of our physics faculties was thirty-nine years; today it is forty-nine years. The large population of physicists appointed to the faculties during the rapid expansion of the 1960's will start to retire at an accelerating rate in the not distant future. According to the manpower study carried for the Physics Survey by the American Institute of Physics, there will be a shortage of physicists for these positions. My personal belief is that we are already seeing the onset of that shortage, for the universities are starting to experience difficulties in finding qualified faculty candidates in certain areas.

The problems of scientific education in the United States are so far reaching that they threaten the nation's fundamental capability not only to maintain scientific leadership but to sustain the level of science that is essential if our standard of living is not to fall. With respect to primary and secondary education, the Survey states:

"The facts on education in science and mathematics are grim. The National Science Foundation report, *Science and Engineering for the 1980's and Beyond*, reveals that the fraction of students who have any contact with physics is so small that we are becoming a nation of scientific illiterates. Our standards for secondary education in science and mathematics are woefully below those of Japan, the Soviet Union, and many of the European countries. The majority of high school physics teachers are underqualified: the supply of qualified new teachers has essentially vanished.

Raising the educational standards in our elementary and high schools presents to the nation a major challenge that demands local, state and national efforts. Dealing with this complex issue is beyond the scope of the Physics Survey, but we would be negligent not to emphasize the critical nature of the problem and not to endorse efforts to improve secondary education, particularly education in science. In this regard, we welcome the re-establishment by the National Science Foundation of the Directorate in Science and Engineering Education."

Although primary and secondary education in the United States are essentially local and state responsibilities, the National Science Foundation can do much to enhance the quality of science education through programs that help to establish communication between science teachers and stimulate the development of new teaching materials. Without attempting to go into specifies on such programs, it is no exaggeration to say that such steps are vital to our scientific future.

Undergraduate science education is also a matter of concern, for the colleges are finding it harder and harder to maintain the quality of their programs. The Survey reports:

"The status of undergraduate education in physics is being surveyed by the Committee on Education of the American Physical Society (APS). Preliminary studies reveal the need for concern on such issues as updating and augmenting undergraduate instructional equipment, facilitating faculty and student participation in research, strengthening visiting scientist programs, and encouraging the development of new courses and curricular. There is, for example, a real need for senior-level courses in plasma and fluid physics. The creation of the College Science Instructional Program by the National Science Foundation is a welcome step toward enhancing undergraduate education. We urge the colleges, univerities, and federal agencies to be responsive to the findings of the APS Committee on Education, as well as forthcoming studies by other interested groups."

The major focus of the Physics Survey is on physics research. University-based research emerged as a central theme of the Survey, for the universities carry out more than half of our basic research in physics while, in the process, they train the next generation of professional scientists. This integration of basic research and professional training is generally regarded as a special source of strength to physics in the United States. The Survey points out that the majority of this research is carried out by small research groups working in university laboratories (as contrasted to research primarily organized around major national facilities). This style of physics is showing signs of serious erosion due to problems that have accumulated since the early 1970s. To quote the Survey:

"In the universities, the various fields of small-group research face a number of similar problems. Foremont is a critical need for laboratory equipment or instrumentation. Inadequate support for instrumentation in the United States was identified as a growing problem in the early 1970's in the previous Physics Survey (*Physics in Perspective,* National Academy of Sciences, Washington, DC, 1972). The situation has steadily deteriorated since then. The most recent studies, *Revitalizing Laboratory Instrumentation* (National Academy Press, Washington, DC, 1982), and *Academic Research Equipment in the Physical and Computer Sciences and Engineering* (National Science Foundation, 1984), report that essential instrumentation in university research laboratories is obsolete or simply nonexistent. Lack of up-to-date equipment is cutting off the universities from forefront research. The research groups are losing their ability to compete on an international level, and our students are not being trained in the state-of-the-art techniques needed by industry and government. There is a shortage not only of larger pieces of equipment, such as laser systems, molecular-beam epitaxy machines, and surface-scattering apparatuses (which can cost from a quarter of a million dollars to more than $1 million), but also of equipment such as superconducting solenoids or high-vacuum systems (which can cost $50,000 or more), and even of small instruments like oscilloscopes and signal generators."

The National Science Foundation has broad responsibility for assuring that the United States sustains the level and quality of basic physical science that is essential for its needs. The NSF must play a strong role in addressing the issues of science education at all levels if we are to have any hope of pulling out of our downward spiral in scientific literacy. It is on NSF's role in university-based research, however, that I would like to address my most specific comments.

When the National Science Foundation was founded most of the university-based research in the United States was supported by the Department of Defense. As the NSF grew, it's role remained predicated upon the assumption that a major portion of support for university-based research in physics—approximately half—would come from other agencies. Since the early 1970's there have been two major changes in the posture of the NSF. First, the mission agencies, particularly DOD, have largely lost interest in basic research in the universities. When the DOD withdrew support, NSF did not have the resources to replace it. As a result, a major portion of the base of support which drove U.S. science during its ascendency in the 1960's was lost. In addition, NSF's own budget did not grow rapidly enough for it to sustain a high level of research in its historic areas. The problems facing university-based research today in the U.S. are largely the legacy of this history.

Our national investment in the physical sciences is too small to meet the needs of the future. To assure continued vitality of physics in the Universities the support essentially needs to be doubled. As a fractional increase this looks large, but it is only large when compared to funding levels that have lagged far behind the real needs. The proper figure with which to judge the support needs is our national R&D effort, for today's R&D programs are the legacy of yesterday's investment in basic research. By any such comparison, the fraction invested in basic research is much too small. If the United States is to sustain leadership in science, the National Science Foundation must have adequate resources to do its job.

Senator **Gorton**. Before I go on to the next, let me ask you one question about which I am curious. Is there a consensus among physicists about which new facility is the highest priority? Is it the SSC or is it something else?

Dr. **Klepner**. I don't think there is a consensus now but I think there is a growing awareness that the SSC is so extraordinary compared to anything which has been done before, that if we are going to go ahead with it, we should regard it as a national program.

The manned space station is being authorized and funds for the hypersonic plane, are being authorized. If you look to the future and consider what large programs we should be undertaking to assure the prestige of the nation, continued excellence in science, eventual economic return, our ability to maintain competitiveness, then the SSC is a natural subject for such a program. It is cost effective.

In the past physicists generally have a good record of building large facilities within budget and on time. On the scale of national programs that we are undertaking right now, the SSC is not particularly large: it is rather modest when looked at that way, I think you would find that most physicists would express enthusiasm for it.

Senator GORTON. Dr. Gray, I gather I have overlooked you. My address here says Washington, D.C. I understand you are from Cal Tech so I will hear you next.

Dr. GRAY. Thank you very much, Mr. Chairman. And I will cut my remarks down even further in the interest of time but my report, my testimony will be in the record.

Senator GORTON. It will be in the record.

Dr. GRAY. It is a great pleasure to be here. And I would like to thank you and the other senators on this committee for supporting the NSF budget. We in chemistry think it is very, very important and the administration's budget is a good one.

I served on the committee to Survey Opportunities in the Chemical Sciences that was chaired by George Pimentel and the executive summary of the report is Appendix A in my written testimony.

Let me just say a couple of things about chemistry. Chemistry is critical in our attempts to discover new processes, tap new sources of energy, develop new materials, feed the world's population, improve health and conquer disease, monitor and protect our environment, maintain our economic competitiveness. And it creates our national security.

The chemicals and allied products industry employs more than a million people, makes annual shipments totaling about $175 billion, and currently displays about a $10 billion positive international balance of trade. I thought I would put that in because we may be one of the few groups left with a positive international balance of trade. And I think it is terribly important for us to keep that and improve on that position.

The problem for the nation is that the current investment in basic chemical research is still historically rooted in the funding pattern that was appropriate to the testtube and Bunsen burner era. That era has long passed.

Today chemical research instrumentation is expensive to purchase and operate. And the cost-benefit ratio is high. To quote from an editorial in Science magazine, "In proportion to its contribution to the advancement of other sciences and its contributions to the economy, chemistry is the most underfunded of the natural sciences."

I want to turn quickly to the NSF fiscal 1987 budget request and get right to the point. Importantly, this request is responsive to the recommendations the Pimentel committee made for increases in funding for instrumentation, for collaborative research aimed at advancing materials chemistry, and for promoting new activities at the interface of chemistry and biology.

The reaction to the report and to the NSF budget requests from industrial representatives has been very positive. In a recent guest editorial in Science magazine, E.G. Jefferson, chairman of the Du Pont Co. states;

All who are concerned that science make its full contribution to national life should study the Pimentel report and its recommendations. They will be convinced that we need full support of the chemical sciences by government, industry and our academic institutions. Society will be repaid many fold for such an investment of resources.

In fact, Dr. Jefferson wrote recently to Senator Jake Garn on the subject of the NSF budget. I would like to quote from that letter in my closing statement.

The administration's proposed 1987 budget provides strong funding for the National Science Foundation and particularly for the NSF's expanded support of chemical research. I am writing to express my hope that these budgets can be passed by Congress at the proposed levels.

At Du Pont we have a long history of corporate research and development. We are convinced of the benefits R&D ultimately delivers to the society. Nevertheless, we acknowledge that academic research is the cornerstone of America's leadership in science, and the NSF remains the key agency for the support of the research and universities.

American industry is heavily dependent on academic science, not only for trained scientists and engineers, but also for the fundamental science that plays a crucial role in the development of new industrial products.

Recognizing this, we at Du Pont have for many years financially supported academic research and encouraged our fellow members of industry to do likewise. But we realize that private sector funds, even at relatively high levels, can at best only augment the funding provided by NSF. In this regard, NSF funding represents an irreplaceable resource for the nation's scientific community.

In closing, I would urge you, your committee, to do what you can to find a way for us to make the recommended investments in the future, a future that will be very much influenced by what we know about chemistry.

The cost is miniscule when weighed against the potential returns. We must encourage a scientific field brimming with opportunities for discovery that will advance human knowledge and strengthen the underpinnings of the major industry, and we must attract a substantial share of our brightest young scientists to this rewarding task. Thank you.

[The statement and questions and answers follow:]

STATEMENT OF DR. HARRY B. GRAY

Mr. Chairman and members of the committee, My name is Harry Gray; I am a Professor of Chemistry at the California Institute of Technology and a newly-elected member of the Council of the National Academy of Sciences. I recently had the privilege and honor of testifying about the National Science Foundation budget before Congressman Doug Walgren's Subcommittee on Science, Research, and Technology of the House Committee on Science and Technology. I am equally honored to be invited to testify here today on the National Science Foundation FY 87 budget request to the Congress and to discuss the recently released report of the National Research Council on opportunities for research in the chemical sciences.

I served on the Committee to Survey Opportunities in the Chemical Sciences that was chaired by George Pimentel. This committee of 26 members—broadly representative of the academic, industrial, and government research sectors, the geographic areas, and the major subdisciplines of chemistry—was organized by the Board on Chemical Sciences and Technology of the National Research Council of the National Academy of Sciences.

The charge to the committee was to describe the contemporary research frontiers of chemistry, the opportunities for the chemical sciences to address society's needs, and the resources needed to explore these frontiers to advance human knowledge and to exploit chemistry's potential for enhancing the well-being of all humankind.

The final report of our committee was published by the National Research Council this past October following intensive review and approval by a panel of peers from other scientific disciplines as well as from chemistry according to procedures of the Academies' Report Review Committee. Appendix A,[1] which is the Executive Summary, provides a brief overview of this report. I will do my best to convey the excitement of modern chemical research that is the heart of the report and to summarize the recommendations we have made, particularly those pertaining to the National Science Foundation. My comments are offered on behalf of the Committee to Survey Opportunities in the Chemical Sciences and its parent Board on Chemical Sciences and Technology.

FRONTIERS IN CHEMISTRY

Chemistry is the science of molecules—how they are made, how they are transformed into valuable new products and materials, and how they can be used safely to improve the quality of life for all humankind.

Molecules and their transformations are central to almost every aspect of our quality of life, and economic strength, yet there remains much that we do not know about the rules that control the molecular game. You can see this clearly in the search for a cure for AIDS, in the questions surrounding the Shuttle disaster, in the search for environmentally sound approaches to the production and preservation of food, and in the search for improved molecular level switching devices for computers and communication devices.

As chemists we are both excited and awed by the recent accomplishments and anticipated discoveries on the horizon at a number of chemistry's frontiers. In the report we call particular attention to current opportunities in chemical kinetics, chemical theory, catalysis, materials, synthesis, life processes, and analytical methods. These are really not new research areas. What is new is an arsenal of now available tools—highly sophisticated instruments—that allow us to explore at the molecular level problems that were previously intractable. The new tools, which include high resolution nuclear magnetic resonance spectrometers, lasers, and computers, are essential—absolutely essential—to make headway in the priority research areas identified in the report.

INTELLECTUAL CHALLENGES

The report contains numerous examples of opportunities for intellectual advances in the chemical sciences. But in this setting it is neither possible or appropriate to try to describe more than a few examples of the range of opportunities that we see for instance in controlling chemical reactivity. A common element is our developing ability to probe the elemental steps of chemical change and to deal with extreme molecular complexity.

Let me mention one example from my own research area that may help you understand the kinds of problems that chemists are now able to address. The research question in its simplest form is this: What is the relationship between distance and electron-transfer rates within molecules? While the question is easily stated, inventing an experiment that will yield the information needed to help us answer the question unambiguously is much more difficult. Recently Judy Campbell, John Richards and I have discovered an experimental approach that has an excellent chance of giving us the answers we need.

The approach builds on some basic chemistry of the element, ruthenium, that has been developed in my laboratory over the past decade. The positioning of ruthenium atoms in a molecule is controlled using site-directed mutagenesis, a technique from the biotechnology arsenal that enables us to design novel proteins.

This part of the work is an extension of the research programs in Judy's and John's labs. The basic idea behind the experiment is to use the ruthenium atom as the source of the electron to be transferred, use a laser to trigger the transfer of the electron from one metal atom to another at a specific point in time, and then monitor the dynamics of the transfer process as a function of time.

This may sound like a very simple experiment. And it would be easy to carry out were it not for the extreme molecular complexity of the system with which we must deal. At times we wish that "Mother Nature" were a little less complex; but without this complexity we could not have life as we know it.

The molecular level detail that we are trying to uncover in this research program is central to advances in understanding electron transfer processes in living systems.

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[1] The appendices were not reproducible.

SOCIETAL BENEFITS FROM CHEMISTRY

Chemistry is a central science that responds to societal needs. It is critical in our attempts to discover new processes, tap new sources of energy, develop new materials, feed the world's population, improve health and conquer disease, monitor and protect our environment, maintain our economic competitiveness, and increase our national security. Because of this responsiveness to human needs, chemistry has become a crucial element in the nation's well-being. The Chemicals and Allied Products industry employs more than a million people, makes annual shipments totalling about $175 billion, and currently displays about a $10 billion positive international balance of trade, second highest of all commodity groups.

Examples of the contributions of chemical research to the solution of important societal problems are provided in the Executive Summary (Appendix A) and in a series of brief vignettes in Appendix E.

RECOMMENDATIONS

The report contains eleven specific recommendations. These, and the rationale for them, are all in the Executive Summary of the report (Appendix A).

The first recommendation calls out priority research areas that the committee believes are especially promising and that should receive special attention, particularly from the relevant mission agencies.

But the report cautions that listing priority areas carries the risk of quenching some adventurous new directions with potential yet to be recognized. It urges that we regard our research support as an investment portfolio designed to achieve maximum gain. A significant part of the investment should be directed toward recognized priority areas but with a flexibility that encourages evolution as new frontiers emerge. A second substantial element in this portfolio should be support of creative scientists who propose to explore new directions and new ideas.

The second and third recommendations deal with the important issues of improving the research and funding links between industry and academic research.

The remaining recommendations all deal with the funding that is necessary to make it all happen. They focus on chemistry in relation to various federal agencies' missions.

The problem for the Nation is that the current investment in basic chemical research is still historically rooted in a funding pattern that was appropriate to a "test-tube and Bunsen burner era." That era is long past. Today chemical research instrumentation is expensive to purchase and to operate, but the cost-benefit ratio for humankind is high. Philip Abelson in an editorial SCIENCE magazine titled, "Federal Support for Chemistry," made the following observation, "Important progress is being made in chemistry. In proportion to its contribution to the advancement to other sciences and its contributions to the economy, chemistry is the most underfunded of the natural sciences." (Appendix B)

THE FEDERAL ROLE IN FUNDAMENTAL RESEARCH

In developing our recommendations for action, the Pimentel Committee recognized that, although industry can itself engage in only a modest amount of the most fundamental and adventurous research because the time horizon for application is remote, it plays an important role in the funding of university chemical research. In this regard we are very pleased that over the past three years industry has increased its funding of basic chemical research in colleges and universities by about a factor of four from $10 million in 1981 to about $40 million in 1985. This industrial support, though modest in total, is extremely important because it facilitates movement of new discoveries into new applications and influences university research agendas. The Council for Chemical Research, made up of representatives from most academic research institutions and from chemical industry, has been effective in improving academic-industrial communication and research funding. But industry can not be expected to pick up the check for long-term, high-risk research activities that are not yet perceived to be important to their future or where they are unlikely to be able to recover a reasonable portion of the benefits to be derived from that research support. It is an appropriate place for public investment, and thus the report calls on the Federal Government both through the mission agencies and the National Science Foundation to increase its support of chemical research.

DOCTORAL EDUCATION IN CHEMISTRY

Although the report focusses primarily on the U.S. research enterprise in the chemical sciences, the well spring of vitality of this enterprise is and always will be the continued entrance of an adequate number of brilliant young scientists. Thus, we are inevitably drawn to examine the health of the educational system that attracts top calibre individuals, nurtures their creativity, and effectively prepares them for their professional careers. And, undoubtedly, the higher levels of professional activity in chemistry depend directly on experiences embodied in the Ph.D. program. This dependence is rooted in the rapid pace of scientific progress over the span of a chemist's professional career. The pace requires ability to cope effectively with and develop new ideas.

In chemistry, we have an educational process that effectively furnishes the stream of talented and well prepared young scientists essential to the continued vitality of the nation's technology enterprise. Our industries rely upon them—on their entering the field and bringing an immediate familiarity with the latest discoveries, the recent scientific literature, and the newest instruments and scientific techniques. Herein lies a substantial basis for the investment of federal resources in the fundamental chemical research conducted in the nation's universities. A main reason for the urgency to increase funding now for basic chemical research in our colleges and universities is the need to provide the best training possible to the current generation of graduate students. If we fail to act now, we risk losing an entire generation of talent.

THE ROLE OF THE NATIONAL SCIENCE FOUNDATION: NSF FISCAL YEAR 1987 BUDGET

The section of the report dealing with the National Science Foundation is in Appendix C. This is a good point to turn our focus to the Foundation's FY 1987 budget request. That request is like the proverbial good news-bad news story. The good news is that increases are requested for important purposes, but the bad news is that the magnitude of the increases is considerably smaller than the needs outlined in the report.

Although chemists understand that budget increases are difficult to justify in a budget climate such as the Nation now finds itself, we believe, nevertheless, that the case for increased Federal funding for basic chemical research in our Nation's Colleges and Universities is compelling. Thus, even if it should not be possible to increase the total Federal investment in R&D, tradeoffs to better serve the nation's economic competitiveness, within this total (i.e., not just NSF), are needed.

Specific increases being requested for the Chemistry Division seem to be very much in line with the recommendations that we have made.

The requested increase for shared instrumentation would allow the Foundation to make a start on providing needed support for ongoing maintenance and operation expenses. We agree wholeheartedly with the goal of doubling the size of this program.

The enhancement for collaborative research activities aimed at advancing materials chemistry, chemical catalysis, and new chemical instrumentation will help in some of the priority areas identified in our report. I am pleased that the Foundation is not now proposing too large a shift in the direction of collaborative research activities, because much time and effort is required to develop truly synergistic collaboration. The vigor of chemical research in this country is likely to continue to be based on individual faculty members working with their students. NSF must continue to allow creative, working scientists to decide independently where the best prospects lie for acquiring significant new knowledge. While collaborative projects do not necessarily constrain individual initiative, one should be cautious about shifting the balance too much.

The Chemistry of Life Processes Initiative was started in FY 1985 following an interim report prepared at the request of OSTP and NSF by a committee led by Pimentel (Report of the Research Briefing Panel on Selected Opportunities in Chemistry) under the auspices of the Academies' Committee on Science, Engineering, and Public Policy. This activity along with the new enhancement for biomimetic chemistry, will accelerate progress in understanding biotechnology at the most fundamental molecular level.

Although computational chemistry is not called out separately as a priority area in our report, we recognized that computational activities were key to progress in each of the priority areas that were identified (i.e., Understanding Chemical Reactivity, Chemical Catalysis, Chemistry of Life Processes, Chemistry Around Us, and Chemical Behavior Under Extreme Conditions).

COMMUNITY CONSENSUS

I would like to point out that since the Pimentel Report was published we have held five discussion meetings with chemical colleagues in different regions of the country to provide a forum for debating the report's findings and recommendations. It is a testament to George Pimentel's leadership and the 350 chemical researchers who suggested topics, prepared commissioned papers on cutting-edge research, or critiqued drafts of the report as it developed, that we have yet to identify a major controversy on the report's recommendations. We have had lots of lively arguments on how chemists can communicate more effectively in the science policy arena, but we seem to have a consensus on priorities.

The reaction to the report from industrial representatives has been very positive. I would like to call your attention to a recent guest editorial in Science magazine (Appendix D). In this editorial, E. G. Jefferson, Chairman of the Board, E. I. du Pont de Nemours & Company, states, "All who are concerned that science make its full contribution to national life should study this report and its recommendations. They will be convinced that we need full support of the chemical sciences by government, industry and our academic institutions. Society will be repaid manyfold for such an investment of resources."

In fact, Dr. Jefferson wrote recently to Senator Jake Garn on the subject of the NSF budget. Let me quote from that letter.

"The Administration's proposed 1987 budget provides stong funding for the National Science Foundation and particularly for the NSF's expanded support of chemical research. I am writing to express my hope that these budgets can be passed by Congress at the proposed levels.

"At Du Pont, we have a long history of corporate research and development, and we are convinced of the benefits R&D ultimately delivers to society. We continue to commit a considerable amount (approximately $1 billion annually) of our resources to scientific and engineering investigations.

"Nevertheless we acknowledge that academic research is the cornerstone of America's leadership in science, and the NSF remains the key agency for the support of research in the universities. American industry is heavily dependent on academic science not only for trained scientists and engineers, but also for the fundamental science that plays a crucial role in the development of new industrial products, processes and other applications.

"Recognizing this, we at Du Pont have for many years financially supported academic research and encouraged our fellow members of industry to do likewise. But we realize that private sector funds, even at relatively high levels can at best only augment the funding provided by NSF. In this regard, NSF funding represents an irreplaceable resource for the nation's scientific community.

"In the more specific area of research in chemistry there are numerous challenges ahead that warrant an expanded role on the part of NSF. I encourage you to consider the summary report "Opportunities in Chemistry" published last year by the National Academy of Sceinces. This report documented the very broad impact that chemistry has and will continue to have on many areas of American life, and it highlighted the practical contributions that those educated in this science can be expected to make in the years ahead. Chemists are especially important to the industrial health of the nation: Two-thirds of them are employed by industry, compared with only a third of our physicists and biologists.

"I understand the many pressures that you and other members of Congress face when considering budgetary proposals. I believe, however, that money allocated to the National Science Foundation represents one of the wisest investments for the future that our country can make. I urge you to view the Administration's proposals in this light and to support them at the present levels during the Congressional deliberations."

Our competitiveness in a range of international markets depends upon our maintaining our present position of leadership in the chemical sciences. There is no area of basic science that offers a more secure investment in the nation's future. And our allies and economic competitors among the technologically advanced countries—Japan, Germany, Sweden, France, and Britain—have expressed considerable interest in this report. They are ready to move forward rapidly in implementing its recommendations and accelerating their efforts in chemical research.

I would urge you to do what you can to find a way for us to make the recommended investments in the future—a future that will be very much influenced by what we know about molecules. And the cost is miniscule when weighed against the potential returns. We must encourage a scientific field brimming with opportunities for discovery that will advance human knowledge and strengthen the underpinnings of a major industry, and we must attract a substantial share of our brightest young scientists to this rewarding task.

California Institute of Technology,
Pasadena, CA, June 30, 1986.

Hon. Slade Gorton,
Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, DC.

Dear Senator Gorton: I am pleased to respond to the questions contained in your letter of May 16.

Question. How much emphasis has there been on chemcial engineering in the [National Science] Foundation's Engineering Research Centers? Should there be more?

Answer. Of the first six Engineering Research Centers, two feature chemical engineering in a prominent role: the Biotechnology Process Engineering Center at MIT and the Systems Research Center at Harvard/University of Maryland. Of the second five Engineering Research Centers, the Advanced Combustion Engineering Research Center at Brigham Young/University of Utah involves chemical engineering to a major extent, and the Engineering Research center for Engineering Design can be expected to involve chemical engineers in its work, as well. Given the cross-disciplinary mission of the ERC's, the current level of participation of chemical engineers in these ERC's seems appropriate.

I might note that there has been little or no interaction between engineers and chemists in these cross-disciplinary centers. While the focus of the centers is naturally on engineering research, there are promising horizons for cross-fertilization between chemists and chemical engineers—for example, in catalysis and in interfacial science and engineering—that might be appropriate for mechanisms such as the ERC's.

Question. What does the [National Science] Foundation's proposed reorganization in chemistry mean to you?

Answer. The reorganization that has been proposed for the NSF Division of Chemistry is a positive step that will enhance NSF's capabilities to exploit the opportunities identified in the Pimentel Report. As you probably know, this proposed reorganization was reviewed and endorsed by the NSF Advisory Committee for Chemistry in April, after extensive discussion. The research community of chemists was also invited to comment on these plans in an extensive article in Chemical and Engineering News on May 12. As an inorganic chemist, I am particularly pleased at the prospect of having all aspects of my subdiscipline brought together in one program within the Division for the first time. I think that this will effectively identify the best research proposals, and I am confident that my peers in other parts of chemistry view the reorganization in the same positive light that I do.

Let me close by expressing my appreciation to you and your fine staff for the invitation to testify before your subcommittee on the National Science Foundation's budget for fiscal year 1987. Please feel free to contact me if I can be of any further assistance.

Sincerely,

Harry B. Gray.

Senator Gorton. Thank you. Dr. Schmidt, I apologize that I am not going to be able to stay for your testimony. I do think, however, you have already heard from the questions here earlier that we are greatly concerned about astronomical sciences.

And I have an eloquent letter from one of my constituents at the University of Washington here which you have not seen. We would be happy to share it with you. We do want your testimony and we are going to look very carefully at your requests.

Senator Rockefeller has already asked questions on that subject so I will leave you with him.

Dr. Schmidt. Thank you, Mr. Chairman. I will be very brief, Mr. Chairman. I have submitted written testimony, and I will just make a few remarks and submit it for the record, if that is all right with you.

Astronomy is part exploration, part basic science. It is the exploration part that captures the imagination of the public, but exploration has been stressed from early history.

First it was on the surface of the Earth as far as the South Pole. Now man's space travel has included the Moon, perhaps eventually all the planets of the solar system, perhaps eventually even the near stars. But there is a limit which is set by the travel time approaching that of a human lifetime.

But this does not end our quest. Light from distant celestial bodies is carrying information to us at the maximum speed permitted according to physics, the speed of light. All we have to do is to catch that information to learn about a universe. We do this by optical telescopes, radio telescopes, x ray telescopes and so on; some on the ground, some in orbit.

There is another aspect of astronomy—the major aspect, really—and that is basic science, basic research. Astronomy is closely tied to physics and it supplies conditions that cannot be found in an earthbound land. The big bang in particular presents energies unattainable with earthbound accelerators.

Elsewhere, in another case, the double quasar mentioned in newspapers last week may be lensed by a black hole with a mass of 1,000 galaxies, obviously not simulated on Earth, or it may be caused by a wrinkle in the geometry of space—fascinating but yet speculative.

As I said before, all we have to do—in quotation marks—is to collect the information the universe is sending us and this brings me to the issue of funding. As mentioned in the written text, the implementation of the recommendations contained in the field report has been slow.

The construction of the VLBA was originally planned to take 4 years. At the present low rate of funding it will take nine. If the national new technology telescope cannot be started in parallel with VLBA, then no major new national telescope will be in operation before the year 2000. By that time the Europeans may well have a larger telescope operating.

At present, several factors are affecting the stability of funding for astronomy. First, there is the budget deficit reduction. Recently, I joined presidents of 27 other science and engineering societies in urging the Congress to save basic research from destabalizing cuts that would jeopardize U.S. economic competitiveness. It has been discussed extensively this morning.

The second factor affecting astronomy is the consequence of the accident of the space shuttle *Challenger*. As I mentioned in the written text, NASA investigators are using the Hubble space telescope and other missions will not be forthcoming until the much delayed launch.

This has an effect on many ground-based astronomers who expect to be guest investigators on space telescopes. Finally, the third effect affecting astronomy this year is the low budget for astronomy in the NSF proposed for fiscal year 1987 compared to other scientific fields.

I am not aware that this is based on any committee recommendation. This is particularly worrisome since the NSF is the lead agency for astronomy. My request is that the NSF budget for fiscal year 1987 be augmented to allow an equitable budget for ground-based astronomy. Thank you.

[The statement and questions and answers follow:]

STATEMENT OF DR. MAARTEN SCHMIDT, PRESIDENT, AMERICAN ASTRONOMICAL SOCIETY

ASTRONOMY IN THE UNITED STATES TODAY

Scientifically speaking, astronomy is in a golden era. In our exploration of the last frontier, the universe, we are finding objects and processes that were unknown only a few years ago. Astronomers are now studying the interiors of stars, the extraordinary environment of black holes, and the first quasars formed, whose light has travelled to us for 13 billion years. In all this, astronomy is closely tied to physics; in turn, astronomy provides opportunities for the high-energy physicists to study matter under the extreme conditions in the Big Bang that cannot be reproduced on earth.

The astronomy community, in each of the last three decades, has assessed the state of astronomy and prioritized instrumentation needs for the coming ten years. The most recent study, sponsored by the National Academy of Science, was finished in 1982 by a committee headed by George Field. The "Field Committee Report" listed in priority order those instruments judged to be most necessary to answer the major scientific questions facing us in the decade of the 1980's.

In the area of ground-based astronomy where NSF has the lead agency role, progress has been slow. The highest priority ground-based instrument, the Very Long Baseline Array [VLBA] was started, but at a very constrained spending rate which, if continued, will lead to stretching out construction for seven more years. Development of mirror technology and design work for the recommended National New Technology Telescope [NNTT] has proceeded at a modest pace. If the construction of the NNTT has to wait until the VLBA is finished, then it may not be completed until the year 2000.

The Administration's budget request for FY 1987 contained a healthy increase for the National Science Foundation. We commend the Administration for its continued support of research. Especially at times when there is a genuine need for reduction of budget deficits, it is important to maintain the research base and the academic environment upon which U.S. technology is built.

We are less pleased with the proposed amount in the NSF budget for astronomy. Astronomy received the smallest proposed increase of any scientific division in the Foundation. Coupled with the deficit reduction cuts and problems with the NASA budget caused by the Challenger accident, such action will severely curtail the U.S. program in astronomy.

NASA's space astronomy program includes not only the development and deployment of hardware, but also the operation of astronomical spacecraft as nationally available resources. Their guest investigator programs, which combine funding for data reduction with use of the instrument, have become a critical component of the U.S. effort in astronomy. Many of the guest investigators supported by NASA are ground-based astronomers who are combining complementary space and ground-based observations to study the underlying physical mechanisms of astronomical objects. The astronomical community has been preparing for the use of the Hubble Space Telescope, the Astro Shuttle mission, the Magellan and Galileo missions, and other space astronomy experiments. Not only were the new data and capabilities eagerly awaited, but the associated NASA support for data reduction and scientific analysis has long been anticipated. With the U.S. launch capability seriously delayed, this support will not be forthcoming soon.

Following, as it does, three years of declining support for ground-based astronomy within the NSF budget, the postponement of much of NASA's space astronomy program is particularly serious. Adding to the problem is the slowness with which new ground-based instrumentation is being constructed, with the prospect that Europe will surpass the U.S. in ground-based optical astronomy facilities.

It is frustrating to stand on the threshold of a major increase of our understanding and have no way to launch our space instruments while, at the same time, the support for use of our ground-based facilities is dwindling. An augmentation of the NSF budget would allow the Foundation to fulfill its responsibility as lead agency for ground-based astronomy.

QUESTIONS OF SENATOR GORTON AND THE ANSWERS

Question. You mentioned that the Foundation's budget request for astronomy has the smallest increase of any scientific division. Before the Challenger accident, was this increase, though small, adequate?

Answer. The Foundation's budget request for astronomy shows an increase of one percent, smaller than for any other scientific division. Even before the Challenger accident, this would have been entirely inadequate.

In the period from FY 1984 to FY 1987 the annual construction cost for the VLBA increased by $6.9M, from $2.5M to a proposed $9.4M. During this time the total NSF budget for astronomy in constant dollars will decrease slightly. Under the present circumstances, the budget for research operations has effectively absorbed all the VLBA construction funds. Excluding the VLBA construction, the funds for astronomical research have decreased by over 10 percent from FY 1984 to FY 1986. The small proposed increase for FY 1987 will do little to alleviate this constricted budget.

It is worth noting that the FY 1984 level of $2.5M for VLBA planning and design work was specifically allocated from the budget for research operations. As such, it represented projects which were closed down or foregone in order to build the VLBA. We view this level of annual support as a fair contribution from the operating budget to the construction costs of this powerful instrument. We do not believe the operating budget for science should supply the entire cost of VLBA capital construction.

Question. Why has support for astronomy been declining within the Foundation? Has this had the concurrence of the astronomical community?

Answer. We cannot answer for the Foundation, but it is hard to understand why such a decline has taken place. It certainly has not had the concurrence of the community. In fact, the NSF Astronomy Advisory Committee has expressed alarm at the low proposed FY 1987 budget. Astronomy is a vigorous, exciting, fundamentally important and intellectually rewarding scientific field. This U.S. is at the forefront and we firmly believe it should stay there. This is only possible with solid, steady budget support.

Question. Even without the Challenger accident, can NASA's programs make up for cuts in gound-based astronomy? Are the two agencies interchangeable as a funding source?

Answer. In astrophysics, NASA has a policy not to support ground-based astronomy. NASA support cannot make up for cuts in the NSF funding for astronomy. Objects newly discovered by space-based instruments almost always require additional observations by ground-based telescopes in order to be completely understood. Thus, NASA's programs actually add to the pressure for the use of ground-based instruments supported by NSF. The interchangeability of the two agencies as a funding source depends very strongly upon the kind of astronomy, and whether it is related to a current NASA mission.

Question. How much of an augmentation of the Foundation's budget for astronomy is necessary to support ground-based astronomers who would have been supported by NASA in FY 1987?

Answer. This question is particularly difficult to answer since we are not sure of the level of support that NASA had intended. We would argue that the augmentation (a) should repair the inequity between the proposed increase and the average increase for the Foundation as a whole ($7M), and (b) free the operating budget for astronomical science from the increase in the capital construction expenditure for VLBA since 1984 ($7M). While the present situation of tightening budgets may preclude an increase of this magnitude, some relief is necessary to maintain the vigor of U.S. astronomy during this period when data from new space instrumentation is lacking.

Question. What does your organization think of the Foundation's proposal to move astronomy into the Directorate for Mathematical and Physical Sciences?

Answer. The astronomical community views this move favorably. The astronomical endeavor is very similar in nature and execution to the other physical sciences. There is a long history of cross fertilization with mathematics, physics, and chemistry.

Question. Does the Foundation need to reform its method of awarding grants so that they include money for the use of research facilities, as well as money for the investigator?

Answer. Ground-based observers have traditionally been in double jeopardy as the granting of research money, by the NSF, and the award of telescope time, by individual observatories, has been done independently. While this may have caused a few hardships in the past, the astronomical community has generally learned how to work with this system. Although there might be an argument to couple the award of time and money, I suspect that this woud turn out to be an excessive financial burden for ground-based astronomy. Also, there are many operational and sociological questions which would have to be addressed if such a change were to be contemplated. We do not recommend adopting such an approach for ground-based astronomy.

Thank you very much. I appreciate very much your being here. And also I apologize for what happens so often.

The first panel gets all the liberties and too many of the questions. That doesn't necessarily reflect upon the integrity or the wisdom of the third panel, but you may leave feeling you have been slighted. I apologize for that.

Mention was made earlier here of numbers of people going into the various sciences. And mention has not been made of those who are in and their general age levels. I would guess that in several years, if there is not an increase in the numbers of Americans going into the various sciences, that the figures on these various charts will worsen because there will be more who are leaving the sciences because of the age of retirement then those who are entering.

Is that a fair worry?

Dr. **Klepner**. May I comment on that because the situation in physics is particularly dramatic. University physicists had a median age of 39 years in 1970. Today it is 49 years. We have aged about half a year per year. We are not going to do that indefinitely. We are going to age into the early 1990's, then we are going to start retiring at an accelerating rate. The universities we are going to have to start replacing those faculties.

I spoke earlier about the difficulty of filling university positions right now. We are just starting to see the problem because the number of positions right now is rather small. We know that the number is going to increase dramatically in the next decade. It is difficult for me to see how we are going to fill those positions.

Maybe we can bring in more scientists from abroad. Perhaps we can stimulate more American scientists to pursue university careers by providing the resources needed for research in universities. If we want to do that, however, we must start now. You can't develop new talent quickly, but we are going to start retiring quickly.

Dr. **Gray**. The suggestion is about the same in chemistry. The Ph.D. production in chemistry in about 1970 dropped by roughly 500 Ph.D.'s per year and has never come back from that large drop of about 15 years ago.

It has maintained a level of 1,500, 1,600 per year. Two-thirds of all American chemists are employed in industry. And it is a tremendous base for industry and so we are very worried that we are aging, we aren't being replaced by younger people. It is very much the same situation in chemistry as in physics.

We simply have to attract more young people into the so-called hard sciences.

Senator **Rockefeller**. When people come into graduate schools, into the science fields and then go on into graduate schools, do they believe at that point for the most part that they want to go into industry because they see the problem we have in this country of a gap between inventing, on the one hand, and applying on the other? Well, industry provides that opportunity and evidently also provides somewhat higher salaries.

On the other hand, as the lay person thinks of very high level people, with very special ability in the sciences, one thinks of an exceptional instinct for research for its own sake.

Has there been a shift in that in any of your various fields, a little more of an instinct towards: Yes, I am interested in research for its own sake, but I also have three children and I can't be sure what is going to happen to educational funding, so I had better get to where life may be more secure as opposed to what it is that got me into this in the first place.

Dr. **GRAY**. That is an understandable question. I think the point that was made by the first panel should be emphasized; that is, at least in chemical research, there is much more of a premium placed on opportunities for research and instrumentation and facilities, much more than on salaries.

I think chemists tend to want to go into industry because the research opportunities have been greater. The differential in salaries is certainly there, but it is not a compelling reason. People look for opportunities because the salary is not going to make one rich anyway.

But I don't think the distribution has changed all that dramatically in the last few years. I think still there are people attracted to industrial jobs and more practical things and people attracted to academic jobs, but what I am terribly afraid of is the academic jobs are deteriorating in the sense of facilities and instrumentation to the point where they are simply not attractive at all to young people. And people are looking for other things to do entirely.

Senator **ROCKEFELLER**. Don't you in the academic community in fact look upon, with some secret resentment and as a threat to the motivation for your students, the power and the amplitude of defense moneys?

Dr. **GRAY**. This is when the chemist always passes the microphone to the physicist.

Dr. **KLEPNER**. There is real concern about the effect of the defense spending on the utilization of scientific manpower in this nation. My own personal concern is that the defense department has given up all interest in basic research.

And I think this is terribly sad when one considers that physics in the United States was really created by the Defense Department after World War II. The great flowering of physics was underwritten by the Office of Naval Research and the other Defense Department scientific offices. They were models of enlightenment and execution of physics. All that has been set by the board.

The DOD needs physicists. The SDI Program is causing increased employment. This program is described as a long-term effort that stretches into the future. It is very difficult to see where the scientists are going to come from. And it is quite clear that the SDI will distort the employment of physicists in the country.

The SDI is going to take physicists away from universities. It will take them away from industrial research. It will take them away from other Government laboratories. There is potentially a huge program. For this country to undertake such a large program, we must have adequate manpower resources. We certainly have not been investing in them.

Senator **ROCKEFELLER**. It is a very large cultural statement, too.

Dr. **Gray**. If I could add something seriously on that point, what we are finding in chemistry is that talented chemists, there aren't enough to go around. And they are being taken out by all kinds of mechanisms. This is one.

The tremendous emphasis on defense research and the SDI Program chemists are broadly trained, lots of them are computer experts, know a lot of physics and mathematics in many cases, so there is a tremendous demand, actually, for chemists in other areas. So they are, in fact, being attracted into the SDI Program to do electronics, computers or whatever.

Teachers of chemistry are being taken into computer science. This was mentioned in the first panel, the lack of people in this area, so chemists are making up some differences there. The result is, you look around and all of the crucial areas of chemistry are tremendously undermanned because of this resource problem.

The fact is we don't have enough trained people in hard science to go around. And so we are filling gaps here and there. And there are absolutely crucial problems left both in teaching and research in chemistry, at the center of chemistry, that are going hungry right now because of this defection, if you like, of chemists into other areas where there is more money, there is more instrumentation, there is more everything. It is both a research and education problem for the country.

Senator **Rockefeller**. Earlier I was trying to raise a question of motivation. Why is it people want to get into the sciences?

In Japan there is one national curriculum, so that obviously every third grade and every eighth grade student, every 12th grade student is doing exactly the same thing, wherever that be in the country. And there are in that obvious advantages. That is, if it is the national purpose to encourage chemistry, physics and whatever, then that can be inserted into the national curriculum. That creates not only the culture but also the national purpose and aspirations.

Our country is the opposite of that. We have however many thousand school boards with however many thousand curriculums, highly disorganized. That would have some bearing, wouldn't it? In other words, we rely more on the market forces, on things other than real national purpose.

It is a more diffused national purpose. Nobody was talking about SDI 3 or 4 years ago, and now it is considered a major assault on the chances for people going into non-defense research, for our ability to compete overseas, and for a variety of other things.

Our students are subject to external national purposes quite apart from what we say as a matter of educational policy. You are always fighting that, aren't you? You have great and total uncertainty built into any view of the next ten years that you might have?

Dr. **Gray**. I think we have plenty of curious young people in this country, people who want to go into science. I think our job is to allow them to do so, make it possible for them to do experiments and exploring and so forth and not turn them off.

I don't think we have to recruit them actively. I think they are there. All we have to do is provide mechanisms to encourage them.

Senator **Rockefeller**. Weren't the top five winners of the Westinghouse award this year all Asians?

Dr. **Gray**. I wouldn't be surprised. It wouldn't surprise me, but I don't know.

Senator **Rockefeller**. Dr. Schmidt, I am very fond of the Greenbank Radio Observatory, as I expressed earlier. And I am concerned with the 1 percent increase for astronomy in this generally very good budget as opposed to the other aspects of it. Are you worried about that?

Dr. **Schmidt**. Very much indeed, Senator. One of the bases of our worry is that the VLBA is making such slow progress. As I mentioned, it won't be 4 years but 9 years in total before it is completed.

The entire program of implementation of the recommendations of the field committee is slowed down by that. The VLBA was not its major, although its top ground-based recommendation of the field report. That was for a decade.

If it takes 9 years to really complete the VLBA, the next one in line, the National New Technology Telescope will simply come to a dead stop. That is one thing. The other thing is simply the budget for research, that is for astronomy research operations with the VLBA excluded has been slowly declining over the last three years. The current 1 percent increase will exacerbate that situation very badly.

Senator **Rockefeller**. Gentlemen, I am grateful to you and appreciate your coming long distances.

Dr. **Gray**. Thank you. We appreciate your support.

Senator **Rockefeller**. The hearing is adjourned.

[Thereupon, at 12:17 p.m., the subcommittee adjourned.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

UNIVERSITY OF WASHINGTON,
Seattle, WA, March 24, 1986.

Department of Astronomy, FM-20

Senator SLADE GORTON,
Senate Office Building,
Washington, DC.

DEAR SENATOR GORTON: The shuttle disaster has had many unfortunate repercussions, but there is one that is not widely known and that I hope to bring to your attention with this letter. In brief, it has had an unexpectedly immediate and disastrous effect on American astronomy.

Aside from major national efforts, involving government and government-sponsored laboratories, astronomy is a small and modestly-funded science. Most astronomers doing research are in colleges and universities, where their and their students' work is supported by small grants, primarily from the NSF. Although there has always been too little funding by NSF to support all of the meritorious proposals submitted to it, the past has in no way been the calamity that characterizes the present. I believe that the nature of the problem has to do with the difference between the ways that NSF and NASA support science. As you may know, NSF grants are awarded on a competitive basis primarily to individuals, regardless of and independently of the research facilities to which they have access. To carry out a particular project, I, for instance, will have to write at least two proposals, one to the observatory to use the telescope and one to NSF for financial support for the research. In each case, there are usually three times as many qualified proposals as there are awards, and it is frequently a matter of luck as to whether there is a match; sometimes telescope time is awarded but there is no money to support the research, and sometimes money is awarded, but the telescope time is declined. This kind of chaos has been with us for many years and we are somewhat resigned to it and do the best we can. NASA, on the other hand, has a much better scheme. Its orbiting telescopes, particularly the IUE, a small ultraviolet telescope which has performed splendidly now for nine years in space, and the shuttle-borne telescopes ASTRO and Hubble Space Telescope, are so expensive in the first place that NASA cannot afford to give time to astronomers to use them without being sure that the data will be used fully and expeditiously. Therefore, NASA awards both telescope time and support money at the same time. For IUE, for example, an astronomer will typically be awarded 10-20 hours of telescope time and $10-20,000 of support, which will cover travel to NASA for the observations, student salary, summer salary for perhaps two weeks, computer costs and costs of publication. This scheme works very well; IUE has the reputation of being one of NASA's most productive and efficient efforts.

This brings me to the point of this letter: NSF, knowing that NASA has plans to support astronomers who competitively receive time on the Space Telescope and ASTRO, has severely cut its own budget for astronomy. And now, following the Challenger accident, the Space Telescope has been delayed and ASTRO has been put off indefinitely, and many of us astronomers are left without any support from either government agency.

I will describe my own case as an example, with the assurance that I know of several others like mine. After many years of modest NSF support, I have now been told that my grant has come up for renewal at an awkward time and that there will be no money for my research. Not only has Gramm-Rudman caused a shortage of funds, but prior to that, the Director of NSF had decided that the astronomy program should be cut severely compared to all other programs in the NSF in the next budget. Therefore, prospects for present support are nil and for future funding are very uncertain. Although the NSF officials with whom I have talked do not try to explain the cut in astronomy's support, it seems clear to us that there has been the implicit assumption that NASA's support of Space Telescope projects will fill the gap. Now, of course, there is no prospect of that happening for at least two years (we who propose to be users must wait until at least a year after launch before we can expect out time to be scheduled and funds to be allocated).

Therefore, we are left without research support for an indefinite period. I have three graduate students doing doctoral theses and two additional students doing research for pre-thesis training. All six of us must now stop, as my grant has run out; there is no more computer money (nothing can be done in modern astronomy now without the aid of the computer). Furthermore, against very stiff competition, we have been awarded a large amount of telescope time at the National Observatories, scheduled in May and June, and have no funds to process the data.

Our program is not unproductive. I have published nearly 300 research papers and several scholarly books and my 12 former PhD students hold responsible jobs at schools and labs all over the country. One of my present students is possibly the best student we have ever had and I suspect may be the best graduate student in the U.S. at this time.

Thus a vigorous and productive research program has been brought to a standstill, with no help in sight. Others are similarly suffering (for instance, the astronomer in the office next to mine has also been cut off completely by the NSF). The problem is especially vivid for me, of course. When your boat is sinking, you suddenly become unusually aware of the faulty design of the ships. But I hope that the general problem that now faces, in a most immediate and unexpected way, the life of American astronomy is clear from this letter. NSF has moved to reduce its support of individuals doing astronomy and now the shuttle disaster has cancelled any possibility that NASA can help right away.

I hope very much that you can bring this problem to the attention of the Director of the NSF and that American astronomical research can be spared a second truly damaging disaster.

Yours sincerely,

PAUL HODGE,
Professor of Astronomy.

AMERICAN SOCIETY FOR MICROBIOLOGY,
PUBLIC AND SCIENTIFIC AFFAIRS BOARD,
Washington, DC, May 7, 1986.

Hon. SLADE GORTON,
Chairman, Subcommittee on Science, Technology, and Space, Senate Committee on Commerce, Science, and Transportation, Hart Senate Office Building, Washington, DC.

DEAR CHAIRMAN GORTON: The American Society for Microbiology (ASM) wishes to submit this statement for the record on the Fiscal Year (FY) 1987 budget for the National Science Foundation (NSF). The ASM is the largest single biological life science organization in the world with an active membership of over 34,000. Many of these individuals are engaged in biological research and a sizable number are recipients of grants administered by the NSF. A large number of areas are represented in their interests, including molecular genetics, biotechnology, photosynthesis, nitrogen fixation, regulation of gene expression, immunology and ecology.

The ASM endorses the President's proposed FY 1987 budget of $1.686 billion for the NSF. The President's budget request provides for a modest increase in the level of funding to help cope with the rising costs of research and research training in scientific disciplines. Although the nation is in a period of budgetary stringency, and Congress is working to identify the spending reductions called for in the Gramm-Rudman-Hollings Balanced Budget Act, we need to be cautious not to decimate relatively modest federal programs such as NSF that, in relation to relatively small investments, bring disproportionately large benefits to the country. The NSF is a force for present and future progress in all areas of basic science. To sustain the current level of competitive standing of the U.S. in the international world of science, we must maintain, and even increase, our level of investment in basic research. We are all aware that there is a direct connection between current progress in basic science and subsequent tangible progress in innovative practical applications. The relatively small investment in NSF has had a positive effect on public welfare and will continue to do so in the future if adequately supported.

We hope that Congress will not permit the NSF budget to decrease in FY 1987, or even to be maintained at the fiscal 1986 "sequestration" level without an increase for inflation and some growth as proposed in the President's budget. A look at current history shows a deteriorating situation for NSF's budget. Between 1985 and 1986, Congress appropriated an increase in NSF's budget of only 1.5%, far less than the rate of inflation. In March of this year, NSF's 1986 budget suffered futher erosion by the 4.3% reduction required by the Gramm-Rudman-Hollings law, and NSF's current budget of $1.490 billion is $17 million below the FY 1985 level.

The FY 1987 budget request of $282.4 million for the NSF Biological, Behavioral and Social Sciences (BBS) Directorate reflects the modest program levels proposed in the President's budget. Under the proposed budget, we calculate that the number of individual research grant awards in the molecular and cellular biosciences would decrease slightly from a total of 1,675 in FY 1985 to a projected 1,645 in FY 1987. The average dollar amount per award is projected to increase only about 10% over two years (from about $68,000 in FY 1985 to about $75,000 in FY 1987). This does not take into account the actual cost of doing research when one considers inflation and the high cost of utilizing ever more effective but expensive modern techniques. Any decrease in the FY 1987 proposed budget level would necessarily bring about a reduction in basic science activity. In our view, this segment of the NSF budget should be the most resistant to budgetary erosion, because it is the most important in furthering economic development and maintaining our international advantage in science and technology.

The NSF sponsors essential opportunities to train both graduate students and postdoctoral scientists. To ensure an adequate supply of scientists in the near future, we need to continue these programs of human resource development. In FY 1985, the BBS provided support to 2,056 graduate students. The 1987 budget proposal for the BBS Directorate requests support for 2,041 graduate students, a decrease of 15 from the FY 1985 level. The numbers of postdoctoral scientists supported by BBS is slated to drop from 952 to 928 over the same time period. We believe that in fact the total number of trainees should be increased, or in the worst case, not be diminished below present levels. Training adequate numbers of new scientists is a very critical issue at this time. There is currently a decline in the number of Ph.D.'s matriculating into the biomedical sciences when, scientifically speaking, we are in the midst of an explosion of research opportunities in the biomedical sciences that are unparalleled in history. In order to take advantage of these opportunities, we must make sure that we continue to train adequate numbers of qualified young men and women for careers in biomedical research. The yields of education are gathered in the future, and activities of today will affect our nation's progress in years to come.

We also urge Congress to recognize the growing need to upgrade or replace aging research facilities in order to maintain and improve the infrastructure underlying basic science and engineering. We urge that funds for upgrading research facilities be earmarked as additional funds designated specifically for this purpose. To finance needed facilities renewal with funds previously invested in research efforts would ironically defeat the purpose of renewal by damaging just the activity one wishes to serve.

The NSF budget proposal calls for plans to encourage a interactive, interdisciplinary science by setting up a number of collaborative minicenters. These novel efforts seem to constitute a positive move toward encouraging fruitful collaboration among basic scientists and engineers. As argued above, the funds used to strike out in this new and potentially valuable direction should be new additions, identified as such, and should not have the effect of reducing the tried and true, successful avenue of selecting for funding the very best of the investigator-initiated individual research grants.

To summarize, we support the NSF FY 1987 budget request as the minimum needed to establish stability and continuity for important scientific research programs. Also, although we support the establishment of interdisciplinary research centers and the measures to revitalize our research facilities, we strongly recommend that this be done with new money, not by reducing support for the investigator-initiated individual research grants.

The ASM appreciates the opportunity to comment on the FY 1987 budget request for NSF and stands ready to provide additional information or assist in any way possible during the budget process for NSF.

Sincerely,

MOSELIO SCHAECHTER, Ph.D.,
President, American Society for Microbiology.
HARLYN O. HALVORSON, Ph.D.,
Chairman, Public and Scientific Affairs Board, ASM.
MONICA RILEY, Ph.D.,
Chairman, Committee on Genetic and Molecular Microbiology, PSAB.

AMERICAN CHEMICAL SOCIETY,
Washington, DC, May 15, 1986.

The Hon. SLADE GORTON,
Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, DC.

DEAR MR. CHAIRMAN: As the world's largest scientific society dedicated to a single discipline, the American Chemical Society offers the following observations on the Administration's budget request for the National Science Foundation for FY 1987. These comments will focus primarily on research in the chemical sciences.

The NSF Organic Act directs the Foundation to initiate and support basic research and education programs at all levels. The Foundation's importance to the scientific research and education enterprise in the U.S. is beyond dispute. NSF bears the major responsibility for maintaining the health of basic scientific research in the U.S. It accounts for about 28 percent of federal support for basic research in academic institutions and maintains U.S. scientific strength by funding research in all fields of science and engineering. It is in the best interest of the country for Congress to fund the NSF at least at the level proposed by the Administration for FY 1987. Under this proposal, support for Research and Related Activities would increase from the FY 1986 Gramm-Rudman-Hollings figure of $1,294.1 million to a total of $1,479.0 million in FY 1987, representing an increase of $184.9 million or 14.3 percent.

While many features unite the various scientific disciplines, these disciplines differ in their organizational patterns and in their top-priority research needs. For example, in high energy physics, an accelerator may hold the key to progress; in astronomy, a large telescope may be central to future advancement. Progress in chemistry today arises from a significant number of small but well-equipped laboratories.

What happens in these laboratories is very important to societal needs and for the economic competitiveness of this Nation. Due to its nature, chemistry inherently makes contributions to our national progress that are most impressive. Our entire physical world is made of material that lends itself to preservation, substitution, and transformation. These activities are carried out through chemical science and technology. Most scientific disciplines, ranging from molecular biology to astronomy, make use of chemistry. A large number of industries use chemistry in the manufacture of their products. The routine analytical sciences which support the nation's health systems use chemistry. Chemistry is truly a pervasive science.

The recently published National Academy of Sciences/National Research Council (NAS/NRC) Report, "Opportunities in Chemistry," details how advances in the chemical sciences can be the key to future progress leading to new processes and materials, more energy and food, a cleaner environment, and better health for the citizens of the world. These advances are dependent upon ideas and experimental results emanating from basic research studies.

The support of the National Science Foundation is essential to the vitality of the research base residing in our academic institutions. In fiscal year 1984, NSF provided 47 percent of the federal obligations for basic research in chemistry performed by universities and colleges; most of this support was contributed by the NSF Chemistry Division.

The American Chemical Society endorses the recommendations of the NAS/NRC Report that states that the NSF Chemistry Division budget should be doubled over a three-year period. The Society likewise endorses the following emphases in the FY 1987 request for the NSF Chemistry Division:

Initiation of a five-year plan in shared instrumentation to fund ongoing maintenance and operations support associated with new instruments, and increased allocations for dedicated instruments in FY 1987. The ACS, as well as the NAS/NRC Report, recommends that annual operating and maintenance costs be built into the NAF shared instrumentation program, and that funds for dedicated instruments be increased. In addition, there is an initiative in computational chemistry. The ACS supports this initiative which will effectively integrate use of computers by researchers.

Support for collaborative research activities in materials chemistry, chemical catalysis, and development of new modern instruments, as well as collaborative and individual investigator projects in the chemical underpinnings, of biotechnology. These research areas are among the fields of study which the Academy Report identified as providing opportunities for significant intellectual advancement that will also help yield social and economic returns for the United States.

Increase of the average grant size in FY 1987 over the FY 1986 figure.

While the overall increase of 17.6 percent above the FY 1986 Gramm-Rudman-Hollings figure in the Chemistry Division's budget is healthy, it falls short of the 25 percent increase recommended in the Academy Report. Nevertheless, it is an important step in the right direction that must be preserved in the FY 1987 budget process, and maintained in future fiscal years. The ACS urges Congress to support this requested increase in chemistry, which is small when compared to the potential benefits to the economy and our society as a whole.

The ACS believes that as a nation we must insure that the human resources needed by our industries are well-trained and educated. The Foundation is the lead federal agency that attends to the overall health of the academic support structures that produce the Nation's scientific and engineering manpower. Without this continued NSF support, the Nation will be deferring the training of numbers of scientists and engineers who are critically needed by U.S. industry. Chemistry is an especially crucial area since chemists make up the bulk of physical scientists employed by U.S. businesses. Our other major comments on the NSF FY 1987 request focus on this support structure and are summarized as follows:

The American Chemical Society notes that the Directorate for Science and Engineering Education will surely require a larger expenditure of funds in future years to accomplish its overall goals. The Foundation is to be commended for its programs in the K-12 areas; however, new programs are needed at the undergraduate level where future scientists and engineers receive their education.

The Society is pleased that NSF is proceeding with a study of the need for new or renovated scientific facilities. The ACS supports a competitive, merit-based peer-review process. Such a process must be the primary mechanism for selection of proposals for large-scale research centers and facilities, as well as for the selection of proposals for research and instrumentation designated for them.

There is broad recognition that continued productive communications between U.S. scientists and scientists in other countries are important to economic development. The ACS supports the FY 1987 budget request for International Activities, but regrets that the Foundation does not seem to have sufficient resources to add new cooperative research activities.

The Foundation is to be applauded for its programs that enhance the participation of underrepresented groups or institutions in research activity and that improve the Nation's scientific and engineering infrastructure. The ACS is pleased that Presidential Young Investigators, Visiting Professorships for Women, Research Opportunities for Women, Support for Predominantly Undergraduate Institutions, Minority Research Initiation, and Research Improvement in Minority Institutions are among those programs with a continued funding commitment.

In conclusion, the ACS is heartened to see that the importance of basic chemical research and of education is stressed in the Foundation's budget request. The Society urges Congress to continue support for these areas at a time of fiscal restraint.

Sincerely yours,

George C. Pimentel.

Structural Engineers Association of California,
Sacramento, CA, June 2, 1986.

Senator Slade Gorton,
Chairman, Senate Subcommittee on Science, Technology, and Space, Washington, DC.

Attention: Ms. Cassie Phillips

Dear Subcommittee Members and Staff: As the traditional U.S. leaders in the development of seismic design and construction codes and practices, and as practitioners from the State that has the greatest seismic risk, the Structural Engineers Association of California (SEAOC) feels compelled to inform you that we strongly believe the current NEHRP is being seriously misdirected. More specifically, we strongly object to the recent policy decisions by the National Science Foundation that emphasize technology development (long-term potential improvement of earthquake design practices) at the expense of (1) research on issues that have promise for improving design practices in the near term (next several decades) and (2) the application of research results (technology transfer). We, therefore, respectfully request that this letter be entered as part of the testimony during the upcoming Senate deliberations on the NEHRP.

While we appreciate NSF's long-term commitment, the result of the current sole emphasis on "technology development" is that it will negatively impact billions of dollars in construction in the near term. Design issues/parameters that need to be investigated immediately because they impact the potential for unsafe or uneconomical designs are not being properly addressed under the current NSF doctrine. What we have found to be particularly aggravating have been NSF's written and verbal comments to us stating that they do not wish to spend their funds researching today's design approaches (referred to by them as old ideas) because they want to put their money into "super computers", tomorrow's approach (in their view, not ours).

Also of concern to us is the fact that only 7 percent of the current annual funding of the NEHRP is being devoted to technology transfer (e.g., the transfer of technical information between the research community and the practicing professions). Spending such a small percentage on technology transfer implies to us that (1) the potential for applying the results of research work is undermined and (2) there is little if any emphasis on communication between practitioners and researchers; as a result, valuable research results may never be exposed to practitioners, or researchers may embark on projects of no concern (potential or real) to practitioners.

What is needed in the NEHRP is a balanced approach that emphasizes (1) technology transfer between researchers and practitioners; (2) applied research on issues that are of current concern to the professions involved; and (3) research on issues that will provide real or potential improvements in design practices (technology development for the future).

Given the traditional and single-minded interest of NSF in "basic research", we are convinced that NSF will not, in the short or long term, seriously concern itself with the solution of applied problems. At the same time, we are aware of public statements by officials of the Federal Emergency Management Agency (FEMA), the lead agency for the NEHRP, that indicate to us that FEMA advocates a policy that is more appropriate for the solution of the nation's earthquake problem: an emphasis on applied research and its application.

Accordingly, SEAOC offers the following recommendations:

(1) that NSF be specifically instructed to use a designated percentage of its NEHRP funding (we recommend 50 percent) for the applied research on current problems;

(2) that a designated percentage of NEHRP funding (we recommend 25 percent) be utilized for technology transfer (if NSF is unwilling to provide sufficient funding to meet this goal, then the appropriate amounts should be transferred from NSF directly to FEMA); and

(3) that a limit be designated for the percentage of NSF NEHRP funding to be spent on "technology development" (we recommend 25 percent).

We realize that these are very specific recommendations, but strongly believe that such specific directions are necessary, given the independent nature of NSF and the fact that the mission-oriented nature of the NEHRP is in direct conflict with NSF's traditional role ("pie in the sky basic research"). Maybe what we really need in NSF is the resurrection of RANN (Research Applied to National Needs).

Sincerely,

EUGENE E. COLE, *President.*

STATEMENT OF FEDERATION OF BEHAVIORAL, PSYCHOLOGICAL AND COGNITIVE SCIENCES

This statement is prepared by the Federation of Behavioral, Psychological and Cognitive Sciences. The Federation, established in 1980, is a coalition of 13 scientific societies with combined memberships of over 90,000. The Federation's interests include research on behavioral, psychological and cognitive processes and their physiological bases and its application to education, health and human development. We are pleased to comment for the record on the reauthorization of the National Science foundation.

As scientists we are pleased with the Administration's active support of Federally funded basic research, as reflected in the proposed NSF FY87 budget. It is important to the nation to maintain a strong Federal role in basic reseaarch even as the Congress is making major steps to reduce the Federal deficit. In fact, consistent funding for NSF, whose sole mission is to support basic science, now is more important than ever.

Research results cannot be bought on a short time scale. Neglecting basic research this year means fewer gains in subsequent years. We will not be able to remedy this deficit by increasing research spending at that later time. Good research requires attracting good people to work on important problems, training new researchers, obtaining basic results and working out their applications. None of this can be done quickly; the investment in ideas, methods, and applications must be made now. That is why it is important for the government to maintain and enhance, wherever possible, its support for basic research.

In this testimony we would like to call to the Subcommittee's attention the critical importance of research in the behavioral and cognitive sciences and science education.

BEHAVIORAL AND COGNITIVE SCIENCES

The human mind is really our biggest economic resource. The prospects of increasing human productivity lie in improving the productivity of the human mind. One way is by using technology to augment human thinking. Another is through researach on cognitive processes, which has the potential of enhancing our own abilities to think and solve problems and to improve education and training.

The nation faces serious difficulties in adjusting to new information technologies in the work place and in finding productive ways to utilize new technologies to increase the productivity of our industrial and educational institutions. Results of research in behavioral and cognitive sciences are already being used in the design of new human-machine systems, the development of programs of training and education and the improvement of the working environment for many in our nation's work force.

Traditionally one thinks of automation in terms of job productivity and job availability. However, automation affects the role of the supervisor of complex equipment and systems. Examples are airline pilots, power plant control room operators or intensive care nurses. These jobs can shift from boring (when everything is running smoothly under computer control) to overwhelming (during an emergency) in brief periods of time. Technology assists in performance, but it raises a new set of issues: Should systems make their own decisions? Should they inform the operator of every action they take? Do these systems create or eliminate workload? Much of the basic research that will help answer these questions is in the areas of decision making, problem solving, perception and motor skills.

Continued improvement in the use and devleopment of technology requires solutions of fundamental scientific problems regarding the nature of human understanding, learning and motivation. We need to understand more about the cognitive skills and knowledge required for successful performance in technical domains. We need to study how people understand technological systems in order to assure an optional design for human use and comprehension. As we become increasingly dependent on electronic graphics for communication, scientific progress in understanding thought processes will contribute critically to the design of computer-based visual displays. Characterizations of the mental models that people use in reasoning provide a basis for better design of technical information systems and training in the use of technical systems.

In addition, recent basic research on visual perception and attention and spatial orientation is now changing, for example, our understanding of nighttime driving. These results have implications for driver education, night driving speeds, and headlight and highway lighting requirements.

How do people rapidly identify the meaning of a visual symbol? Perhaps more interesting, why is it that people who have large vocabularies are quicker at recognizing simple words? What sort of information retrieval system gets better as its data base increases? Substantial advances in our understanding of word recognition are made by exploring computational parallels of the process. An area of increasing importance is psychobiology, an area which links research in brain processes with our understanding of behavior. Fundamental insights into the biological basis of memory, for example, can be expected in the coming years.

SCIENCE EDUCATION

The need for strengthening our nation's educational programs in mathematics, science and technology is broadly recognized. In turn, this means that we need to improve our understanding of the process of problem solving, comprehension, learning, teaching and testing to guide the development of new educational resources, including the effective use of new computational technology in both instruction and testing.

It is clear that effective science education will result only from the efforts of both the science and education communities. We support interdisciplinary research efforts by behavioral and cognitive scientists, content area scientists and science educators.

Research on problem solving has provided significant new information about cognitive processes and knowledge—demonstrating the kinds of knowledge required for successful problem solving and providing explicit descriptions of knowledge relevant to selected domains in science and mathematics. For example, a predominant view underlying current curriculum design and teaching in science is that students' understanding of scientific concepts is shaped by their instruction. Much care is taken to avoid presenting incorrect principles or concepts. However, students begin their study with strongly held conceptions of phenomena that are explained by scientific principles. Even young children are curious about their world—how things work as well as their classification. When children do not receive much formal science education until high school or college, misconceptions of scientific concepts are allowed to develop. Research shows that their preconceptions are often inconsistent with the principles to be learned but persist even after considerable instruction. As a consequence, students may be able to use their formal knowledge to correctly solve textbook problems but still base their understanding of events of the world on their incorrect preconceptions when taught with commonly used methods.

Many of the research findings are important for educational practice. Recent information about the sources of difficulty in understanding mathematical, scientific and technical concepts provides a basis for development of educational materials and methods for reaching a broader group of students. Research to identify factors contributing to relatively low levels of participation in mathematics and science courses by women and members of minority groups is underway and is suggesting ways in which increased participation can be developed.

Research in cognitive science is not only changing our views of how people learn science and mathematics, it is also shaping a theory of learning in which content plays a central role. The approach implies that much of the research in teaching and learning in science will be done in the context of the science being taught.

As with any science, research relevant to education in mathematics, science and technology is cumulative. It requires continuing support if it is to sustain and expand its impact in education. Continued NSF support is therefore critical.

CONCLUSION

We recommend that you continue to support fundamental science research by reauthorization of NSF funding at the level of the Administration's FY 1987 budget. This is the minimal amount necessary to insure building on your previous investment.

The Federation appreciates the opportunity to submit these comments. Please do not hesitate to call on the Federation staff if we can be of further assistance during your deliberations.

STATEMENT OF THE ENGINEERING EDUCATION TASK FORCE

Mr. Chairman and members of the subcommittee, we appreciate this opportunity to share our views on the National Science Foundation authorization for FY'87. This statement is being submitted for the record by the Engineering Education Task Force, a multi-society task force convened in 1983 to bring together the resources of societies with mutual interests for the purpose of evaluating and developing legislative solutions to critical engineering education and research problems. The Task Force is chaired by Dr. Robert D. Kersten, P.E., Dean of Engineering at the University of Central Florida, who represents the National Society of Professional Engineers [NSPE]. The other participating organizations are the American Society for Engineering Education [ASEE], including its Engineering Deans' Council, and the National Association of State Universities and Land-Grant Colleges [NASULGC].

NSPE is a non-technical professional society representing over 75,000 professional engineers of all disciplines nationwide, who are employed in industry, private practice, government, construction and education. ASEE represents over 10,000 engineers, primarily faculty, and over 250 accredited engineering schools, as well as more than 100 major engineering oriented industries. Over 30% of all students enrolled in institutions of higher education attend the 144 NASULGC member colleges and universities, which include 24 of the nation's largest institutions and multicampus systems of higher education.

In the current climate of intense fiscal austerity, we believe it is especially important to examine carefully all Federal expenditures in terms of their return on investment and the degree to which other sources of funding can be developed. From this perspective, the President's FY '87 budget request for the National Science Foundation clearly emerges as a vital insurance policy guarding our economic welfare and world leadership.

Unlike many areas of the budget, the National Science Foundation supports the development of resources that fuel economic growth. However, because the payoff from this investment in academic talent, training and research is only apparent in the long term, those unfamiliar with the Foundation's programs and accomplishments may not appreciate the critical role played by the NSF. Before looking at the specifics of the proposed budget, therefore, we would like to highlight this point.

It is often said that the National Science Foundation makes only a small contribution to the nation's research and technology base compared with the mission agencies. While it is true that other agencies fund a substantial amount of the nation's research, the largest share of that work is development, directed toward a specific commercial or military application. This type of support is focused on the final product, with the objective to advance the agency's primary mission. The next largest percentage of all federal R&D support is charaterized as applied research, which again is geared toward a mission related result.

These forms of research support are not intended to advance the forefronts of knowledge, but to use the basic research results that already exist to benefit an agency's mission, such as defense. The smallest share of federal R&D expenditures is for basic research, which undergirds all other research and provides graduate students and faculty with opportunities to acquire sophisticated skills and knowledge. And the only agency in the federal structure responsible for advancing both people and research in this way is the National Science Foundation.

Again, though, an examination of the distribution of research funds by agency makes the NSF share of Federal funding of basic research, 16% under the proposed FY '87 budget, appear fairly insignificant. If only basic research performed at colleges and universities is considered, that share grows to 25%. In many areas, however, the unique role that the National Science Foundation plays is masked by these broad statistics.

This is especially true in engineering, where in several disciplines the NSF is almost solely responsible for both the research and talent addressing critical issues at the nation's colleges and universities. For example, in FY '84, the most recent year for which statistics are available, the NSF supported 74% of basic research in chemical engineering conducted at colleges and universities. In civil engineering, the figure rises to an astonishing 93%.

The reason why the NSF share is so high lies in the nature of the work, which is generic and therefore not of immediate interest to mission agencies or industry, but which has some potential for future application. For example, in the civil field, NSF is essentially the nation's only sponsor of fundamental engineering research in structural design, which generates more stress resistant methods for building bridges and other essential elements of the nation's public works infrastructure. This research is desperately needed; in past decades, and even today, these structures have been built using existing, though clearly outmoded, technologies. Without this most basic work, new methods will not come to fruition. And in many fields, particularly engineering, NSF funding serves to leverage non-federal resources, bringing the total investment in research and talent to a higher level than would otherwise be possible.

Clearly, the future growth of our nation depends on research in these and other critical engineering and scientific areas. With the National Science Foundation leading the way, advances in technology can help ensure a bright future.

Given that the National Science Foundation plays such a crucial and irreplaceable role in supporting the nation's academic foundation of research and talent in science and engineering, the need for stable funding becomes obvious. Neither research projects nor the researchers themselves can plan and perform high quality work without stable funding. To stop a research project midterm does not produce half of the expected results; it produces inconclusive, usually useless data. Rollercoaster funding for NSF does not just slow things down, it grinds the research and education enterprise to a halting stop, negating the value of previous investments.

Therefore, while acknowledging that rapid growth of the Nsf budget is not an option with the current fiscal crisis, we hope you and your colleagues throughout Congress will resist the temptation to reduce the proposed budget. The modest growth proposed allows advances in only the most pressing, promising areas such as biotechnology, the encouragement of more women and minorities to undertake science and engineering research and education challenges, and manufacturing processes. The budget request is both fiscally responsible and technologically exciting, no small feat considering the limitations imposed.

In engineering, the budget request is for $185.5 million, a 14 percent increase over the current plan for FY 1986. Still, engineering accounts for only 14 percent of the total budget, a proportion that has not changed significantly over the last decade despite the growing importance of engineering to international technological competitiveness.

While this year is clearly not the time to suggest a massive investment of new funds into the engineering directorate, we do hope the Subcommittee will consider a long-term growth plan that will allow the Foundation to respond better to critical needs in engineering education and research. Last fall, the National Academy of Engineering performed an analysis of the NSF's engineering programs. The final report, "New Directions for Engineering in the National Science Foundation," concluded that "The maintenance of this country's technological leadership cannot be assured in the absence of engineering research at the cutting edge of knowledge. Because the process of technological innovation depends directly upon the quality and quantity of engineering talent * * * it is vital that NSF regard this national challenge as a challenge to itself as an agency and, more specifically, to its engineering directorate."

The report recommends that to meet current needs, the budget of the engineering directorate should grow to between $350 million and $410 million per year. We strongly endorse the Academy's recommendation, and urge you to approve the proposed budget with this goal in mind.

The need for more resources does not stem from a desire to just conduct more research. Rather, the engineering education enterprise is desperately in need of rather substantial improvements. In trying to honor demands for good research and talented people, engineering schools find themselves struggling to maintain superior standards in the face of a variety of problems:

Engineering faculty shortages remain of paramount concern. Currently, one in twelve budgeted positions is vacant. As many as 23 percent more positions are needed to bring the student-faculty ratio close to optimum teaching conditions.

High enrollments at the undergraduate level strain an already sparse faculty and poor facilities. While enrollments have grown over 115 percent over the last 15 years, faculty growth has been approximately 10 percent.

High quality of entering students masks the poor "value added" being provided by undergraduate engineering education. The majority of entering freshmen are in the top 10 percent of their graduating high school class.

Unattractiveness of faculty careers if furthered by limited incentives for bright students to pursue graduate engineering education. Fellowship awards should be increased to equal at least one half of starting B.S. salaries.

Deteriorating physical plants detract from the quality of instruction and research, and reduce the attractiveness of an academic career.

The American Society for Engineering Education is nearing completion of a two year project, sponsored by thirty major corporations, to develop a strategy for ensuring the excellence of the faculty and the academic working environment in coming years. The four task forces of the Quality of Engineering Education Project [QEEP] have produced interim reports with tentative recommendations for schools, faculty, government and professional societies. A copy of those reports are attached for the record.

In sum, we urge you to support fully the FY 1987 National Science Foundation budget request. The NSF plays a vital and irreplacable role in maintaining and enhancing the technological and economic strength of our nation.

STATEMENT OF HOWARD J. SILVER, ASSOCIATE DIRECTOR FOR GOVERNMENT RELATIONS, THE CONSORTIUM OF SOCIAL SCIENCE ASSOCIATIONS [COSSA]

The Consortium of Social Science Associations [COSSA] represents more than 185,000 American scientists across the full range of the social and behavioral science disciplines. It functions as a bridge between the research world and the Washington community. A list of COSSA Members, Affiliates, and Contributors is attached.

COSSA would like to take this opportunity to comment on the proposed budget for the National Science Foundation [NSF] for FY 1987. The overall increase of 13 percent over FY 1986 post-Gramm-Rudman-Hollings levels proposed for NSF is indeed welcome in this era of deficit reduction. Maintaining the investment in basic research is essential to the economic competitiveness and security of this nation. Investment by the Foundation in social and behavioral science research demonstrates a recognition of the substantial contributions these sciences make to those important national goals. Reducing this commitment would decrease the quality of our scientific endeavors and inventiveness.

The 14 percent increase for Research and Related Activities in FY 1987 over FY 1986 post-Gramm-Rudman-Hollings levels is also welcome. We strongly urge the maintenance of that increase during the Committee's deliberations. We are pleased with the large increase in the Information Science and Technology Division where approximately 40 percent of the awards are made to social and behavioral scientists. We are generally pleased that the social and behavioral sciences will share in some of the special emphases of the Foundation in FY 1987 and that Erich Bloch, Director of NSF, has stated that there is an important role for these scientists in the multidisciplinary research at the Engineering Research Centers.

Despite all this pleasure, we are not satisfied. Although, if the FY 1987 proposed funding levels are maintained, the social and behavioral sciences will have finally been restored to their FY 1980 levels in current dollars, support for these sciences at NSF is 27 percent below the 1980 levels in constant dollars (see Exhibit A). In FY 1987 we remain at only 4 percent of the NSF research and related activities budget, a figure that has declined over the past four years, and is a full 2 percent udner the FY 1980 share of that budget.

COSSA believes that the Subcommittee should increase funding so that 5 percent of the Research and Related Activities budget goes to social and behavioral science research. A step in that direction would be to support the actions of the House Science and Technology Committee and the Senate Labor and Human Resources Committee increasing by $3 million the allocation in the FY 1987 NSF authorization to the Biological, Behavioral and Social Sciences Directorate for social and behavioral science research. We believe a 5 percent share is a justifiable goal given the intellectual vitality and ferment in these sciences and their importance to the nation.

We are also not satisfied with the small increase for the Directorate for Science and Engineering Education (SEE). For too many years now the Foundation has stalled in supporting a full and vital SEE Directorate. The small increase proposed for FY 1987 comes on top of a deferral of FY 1985 appropriated funds. This Directorate which supports research in teaching and learning and the education and training of new scientists deserves greater support than it is getting from the Foundation.

Mr. Erich Bloch, Director of the National Science Foundation, argues in favor of basic research "as a force for present and future competitiveness" of the United States. It is clear that social and behavioral science research plays a vital role in competing in an international economy driven by science and technology. Economic competitiveness is achieved not only by developing new and better products, but also by understanding how to interact with those products, how to use them, how to manage the people who make them, in other words, the human behavior side of technological advancement. It is in these areas and others that social and behavioral science research offers the nation the resources and results to compete.

A sampling of the scope and nature of work in these sciences indicates the contributions, those already made and those with great potential, that continued and increased support from NSF will foster:

Advances in theoretical economics and econometric modeling have led to advances in economic forecasting and economic policy. Although, economic forecasting is not perfect, these advances have narrowed the range of disagreement among economists in their ability to help policy-makers. As Herbert Simon has pointed out, the major differences that remain result from different assumptions about how people form expectations, a question that is now the focus of much social and behavioral science research.

Great advances in statistical techniques, such as multidimensional scaling, have produced sophisticated methods of data analysis. These techniques continue to undergo improvement. Refinements in survey research methodology will produce more accurate indicators upon which many of our economic decisions are based. The access of social and behavioral scientists to new generations of computers will enhance these activities.

The need to construct computer models of the international economy to adequately monitor its behavior is another activity where economics are playing a significant role in contributing to U.S. competitiveness.

The theory of rational-decision making remains one of the major accomplishments of the social sciences in the past. Yet recently social scientists have discovered its limitations. The ability to determine how people, from elite policy makers in government and business to the man and woman in the street, make individual choices will strongly affect how the U.S. fares in this competitive world.

Advances in cognitive psychology had led to experimentation that helps us understand how people process information and perform complex tasks. These techniques are being applied to important problems in education, business and professional decision-making, and man-machine interaction. All of these are related to keeping America on top scientifically and economically.

Advances in the study of sensory perception have allowed us to understand how people perceive complex stimuli. The military is particularly interested in auditory and visual perceptions in order for their personnel to operate in multidimensional auditory and visual environments. A modern military reacting positively in complex environments keeps America secure.

Linguists are working on models, many of them computerized, of how children acquire and transmit their native language. These studies have led to the development of instruction packages, some computer-aided, to teach our children and others the language skills, both native speaking and foreign, that are needed to compete in an international economic setting.

Keeping Americans healthy and productive is a major factor in maintaining the competitive edge. The work of social and behaviorial scientists in relating good health to behavorial factors has contributed to increased consciousness of how people control their own quality of life. This is especially true in keeping our rapidly aging population active, productive, and free of dependence on costly health care and maintenance.

Research on criminal careers and career criminals has developed insights into why a portion of the population decides that illegal productive enterprise is more attractive than legal productive enterprise. American loses substantial dollars and sometimes talent to these illegal activities, creating more competitive disadvantages. Understanding why and developing methods to rechannel these activities can lead to more productive lives for these people and safer lives for everyone else.

Studies of agenda formation and agenda setting in organizations demonstrate the importance of the agenda itself in decision-making. How issues reach the national agenda of government often determines the response to those issues. External challenges often focus our energies more than internally determined responses.

How the United States competes internationally depends on our understanding of other governments and cultures. Social and behavorial scientists contribute to that understanding by focusing on international aspects of political, economic, and social choices. Evaluating the impact of different electoral systems on policy making, explaining international economic systems, and examining social and cultural differences of foreign nations have long been the purview of social and behavorial scientists.

Direct utilization of social and behavorial science research on managment styles and worker participation has revolutionized the automotive industry in this country. It is a shame that the Japanese and Swedes paid attention to this research earlier than our American companies. As sociologist William F. Whyte notes, it took the shocks of international competition to persuade industrial leaders in the United States of the need to make basic changes based on the organizational behavior literature.

Research on the interaction between people and technology has led to attempts to revitalize America's shipping and shipbuilding industries. The work of Einar Thorsrud in Norway involving physically re-designing ships and reducing social and status differences among people on the ships, has formed the basis of changes in human resource utilization in the U.S. maritime industry.

Social scientists are being called upon by State governments to conduct policy research and technical assistance designed to aid in the revitalization of U.S. industry.

Examining the impact of Employee Stock Ownership Plans [ESOPs] and worker cooperatives is another example of social science research contributing to better understanding of economic productivity to keep this nation competitive.

A briefer sampling of the research in social and behavioral sciences further suggests the vitality and ferment that make support for these sciences so important to continued economic competitiveness. Topics currently being studied include:

Microsimulation models to help target federal funds to those who most need them;

Human adaptation to stressful environments;

Assessment of risks in occupational settings;

Attracting more women and minorities into science;

Developing computerized models of transporting food from surplus areas to deficit regions in countries around the world;

Youth unemployment; female participation in the labor market; why people change jobs;

Economic constraints on single parent households;

Understanding and predicting human responses to natural and technological disasters;

Comparing the largest metropolitan areas of the country concerning urban land use, population distribution, transportation use, and other critical urban functions;

Social components of alcohol and drug abuse;

Decision-making by farmers and their response to the agricultural crisis;

The impact of different housing arrangements on the elderly;

The impact of inflation and deflation and other economic changes on American families;

The cognitive capabilities of very young children and ways to cope with a teacher shortage for this group.

These lists are by no means exhaustive. They are presented to illustrate that these sciences are conducting research into all areas of human activity that affect the current and future productivity and competitiveness of this nation. As we said last year, research in social and behavioral science does not always yield the solution to the problems it investigates, but increasingly it provides decision-makers with the information to make better and more informed decisions.

We would like to thank this Subcommittee for its support of the social and behavioral sciences in the past. We call on you to move toward more equitable support for these sciences by increasing their allocation within the NSF budget.

Thank you for allowing us to present our views.

STATEMENT OF DR. ALLAN S. HAY, MANAGER, CHEMICAL LABORATORIES, CORPORATE RESEARCH AND DEVELOPMENT, GENERAL ELECTRIC CO.

Mr. Chairman and members of the committee, I am Allan Hay, manager of the Chemical Laboratories of General Electric's Corporate Research and Development Center. It is a privilege to provide this testimony to your distinguished Committee, to bring you the views of the Council for Chemical Research on the important matter of the budget request for the National Science Foundation, in particular the budget of its Chemistry Division. In addition to our Council, we are confident that the National Research Council's Board on Chemical Sciences and Technology endorses fully the statements to be made here.

The Council for Chemical Research [CCR] is an organization of 148 leading universities and 43 major companies. This strong association was formed to maintain and improve the academic and industrial base for U.S. technological competitiveness and the domestic economy. Our purpose is focused on strong interactions between academia and industry and on support for basic research in chemistry and chemical engineering. Our membership includes virtually every research university in the U.S., and companies that do 75 percent of this nation's industrial research in these fields.

The chemical industry of the U.S. supports about a million jobs, annually ships about $175 billion in products and currently makes a net contribution to our international trade balance of about $10 billion. Maintaining this competitiveness requires constant improvement of processes and introduction of new ones. This industry is second to none in its investment in research and development to that end.

The American chemical industry recognizes U.S. universities as the principal source of the vital basic research upon which American industry depends for its knowledge base, and as the principal wellspring of highly trained and imaginative young scientists and engineers. That industry therefore contributes strongly and willingly to the health of the universities. In fact, during the last four years chemical companies have tripled their contributions to chemistry and chemical engineering departments, to an annual level of $80 million.

The industry, however, can carry only a fraction of the expense for this vital base of continued U.S. competitiveness. It is absolutely necessary that the Federal agency responsible for the continued health of our basic scientific enterprise, the National Science Foundation, be given the wherewithal to do its job.

As spokesman for universities and the chemical industry, CCR's enthusiasm for increased funding for chemistry is hardly surprising to anyone, but let me back it up with some facts.

About 70 percent of the chemists in this country are in industry. This is the highest proportion of any science. Physicists and biologists are at about one-third. Only engineers show a higher fraction. The point is that a science so heavily represented in industry will show a strong correlation between academic research and industrial progress.

I hope that you have heard of the National Research Council's report entitled "Opportunities in Chemistry." This report spells out in highly intelligible language the state and the promise of today's chemistry. Hundreds of leading chemists analyzed the state of their art and showed where it could lead. George Pimentel of the University of California did an exceptional job of leadership, editing and maintaining clarity for people not trained in chemistry. The report makes a convincing case that chemistry is central to our scientific enterprise, our economy and our international competitiveness.

Here are some of the highlights of the Pimentel Report, and especially those of its recommendations which bear on the National Science Foundation.

The Report's carefully based observations about today's chemistry show that it combines three attributes to an extent which is unique: it is intellectually exciting, economically promising, and underfunded in relation to its capability for national benefit.

One of the Report's authors and a 1986 winner of the National Medal of Science is Professor Harry Gray of the California Institute of Technology. His words set the stage very well:

"Chemistry is the science of molecules—how they are made, how they are transformed into valuable new products and materials, and how they can be used safely to improve the quality of life for all humankind."

"Molecules and their transformations are central to almost every aspect of our quality of life, and economic strength, yet there remains much that we do not know about the rules that control the molecular game. You can see this clearly in the search for a cure for AIDS, in the questions surrounding the Shuttle disaster, in the search for environmentally sound approaches to the production and preservation of food, and in the search for improved molecular level switching devices for computers and communication devices."

"As chemists we are both excited and awed by the recent accomplishments and anticipated discoveries on the horizon at a number of chemistry's frontiers. In the report we call particular attention to specific current opportunities. * * * These are really not new research areas. What is new is an arsenal of now available tools—highly sophisticated instruments—that allow us to explore at the molecular level problems that were previously intractable."

It is hard to avoid the conclusion that chemistry is a central science. It underlies the discovery of new processes, using new sources of energy, developing new materials, feeding us and the other people of the world, improving health and conquering disease, monitoring and protecting our environment, maintaining our economic competitiveness, and increasing our national security.

There is another characteristic of chemistry, however, which has very timely importance. This is its intellectual challenge and excitement. An example of this is research which probes into the details of very complicated molecular systems, such as the behavior of DNA—the molecule that carries the genetic code—in living organisms. That chemists are able to make progress in that complex and amazing jigsaw puzzle is due to their intellect and the advanced instrumentation now available. Available, that is, if professors guiding university research can find the hundreds of thousands of dollars required for some of these modern tools.

In modern chemistry, then, we have a unique combination of intellectual challenge and economic value, which can help strengthen the economy and bring down deficits if given the required additional investment.

"Opportunities in Chemistry" accordingly recommends some increases in Federal support for basic research in chemistry, increases that are not only minor in terms of the national expenditure for research and development but also trivial in terms of the proven return rate delivered by chemistry and chemical technology.

The chemistry community is very individualistic. In spite of this, the Report's authors courageously identified specific areas within chemistry for special attention. Unquestionably this enhances the credibility of the Report and its recommendations. It is not surprising that Dr. Frank Press, President of the National Academy of Sciences, called the Report "a towering achievement."

The Report recommends that the National Science Foundation should begin a 3-year initiative to increase its support for chemistry by 25% per year for FY 1987, FY 1988 and FY 1989. That may seem excessive at first glance, especially in this time of necessary deficit reduction. What we are talking about, however, are three increases in the neighborhood of $25 million a year, which is miniscule in comparison to the proven return to our economy from investment in chemical knowledge. The $175 billion of economic activity based on chemical technology sets the scale.

And indeed we are pleased that the NSF Director, in spite of current constraints, recommended a 17.5% increase in the Chemistry Division's budget. At the very least, that must be protected. Nevertheless we believe that the increases recommended by the Report are fully justified.

The Report also recommends increased funding by industry. The industrial members of CCR are already doing much, as I mentioned, and intend to continue. Industry, Government and academia must each do its vital part. In simple terms, the formula is: universities do fundamental research (while providing well trained scientists); Government funds it; industry applies it. It is a very successful formula if each of us does our part properly.

To summarize, I should like to close with the words of a guest editorial in Science magazine on the subject of the Pimental Report, written by du Pont's Chairman, Edward Jefferson.

"All who are concerned that science make its full contribution to national life should study this report and its recommendations. They will be convinced that we need full support of the chemical sciences by government, industry and our academic institutions. Society will be rapid manyfold for such an investment of resources."

On behalf of the Council for Chemical Research and myself, I thank you most sincerely for the opportunity to present this testimony to you.

STATEMENT OF LEONARD D. GOODSTEIN, PH.D., EXCUTIVE OFFICER, AMERICAN PSYCHOLOGICAL ASSOCIATION, ON BEHALF OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION

Mr. Chairman and members of the committee, I am Dr. Leonard D. Goodstein, executive officer of the American Psychological Association [APA]. Thank you for this opportunity to submit our views on the authorization of the National Science Foundation for Fiscal Year 1987. APA represents the concerns of more than 87,000 psychologists, many of whom conduct important research with the support of NSF.

In this statement we will address specific areas of the proposed Fiscal Year 1987 NSF authorization of interest to behavioral and social scientists. We will then comment at some greater length on an area of great concern to this Subcommittee, the Administration and concerned Americans: the revitalization of this nation's economic and technological base.

NSF FISCAL YEAR 1987 REAUTHORIZATION

APA appreciates this opportunity to strongly endorse the Administration's proposed Fiscal Year 1987 research budget for the National Science Foundation. We commend the President and NSF Director Erich Bloch for proposing that NSF's authorization be raised to $1.7 billion even in this time of the most urgent Fiscal austerity. These increases have been proposed by the Administration because of its conviction that investing in basic scientific research will improve our competitiveness abroad and our scientific base at home. APA is in agreement with that assessment of the importance of basic scientific research and strongly supports the President's Fiscal 1987 budget request for NSF. We commend the Administration for proposing to increase funding for the Biological, Behavioral and Social Sciences (BBS) Directorate by 12.4 percent over projected Fiscal Year 1986 funding levels.

Increases of this magnitude are needed to restore vigor to behavioral and social science research programs at NSF; these programs are still lagging far behind historical levels of support. It is significant that support of behavioral and social science research has fallen from 6.1 percent of NSF's research budget in Fiscal Year 1980, to 4.1 percent in Fiscal Year 1985, and to 4.0 percent proposed for Fiscal Year 1987. Between Fiscal Years 1980 and 1987, in fact, NSF support for the behavioral and social sciences has actually decreased more than 30 percent when measured in constant dollars.

To help restore the behavioral and social sciences to their 1980 levels of support at NSF, we urge the Committee to concur in the $3 million added to the Behavioral and Social Sciences Directorate in H.R. 4184, which was approved by the House Science, Research and Technology Subcommittee on March 18. These funds would be targetted specifically to behavioral science research in the Behavioral and Neural Sciences (BNS) division, and to regular research grants in the Social and Economic Sciences (SES) Division. It is these areas, behavioral science research and individual investigator-initiated research within the social and economic sciences, that have fared the worst between Fiscal Years 1980 and 1986. Fiscal Year 1986 funding for the BBS Directorate is projected at $247.5 million, some $6 million and 2 percent below Fiscal Year 1985 levels. Some behavioral and social science programs within

BBS, however, are seeing budget reductions of 6.7 percent and more below Fiscal Year 1985.

SCIENCE AND ENGINEERING EDUCATION

APA urges the Committee to reiterate its support for the strengthening of science education activities at NSF. We share concerns expressed by Congress many times that improvement is needed in our nation's science education activities. For Fiscal Year 1987 the Administration has proposed that $89 million be authorized for the Science and Engineering Education (SEE) directorate at NSF. We are hopeful that this increase of $2 million or 2.3 percent over Fiscal Year 1986 levels of support is indicative of the Foundation's intentions to adequately fund science education activities. Further, NSF has repeatedly assured Congress that none of the funds appropriated to the program in either Fiscal Years 1986 or 1987 will be deferred into the future Fiscal Years, as was the case between 1983 and 1985.

We believe, though, that the gradual rebuilding process undergone by SEE has prepared it to efficiently use additional support. Again, we urge the Committee to concur with the recommendations of H.R. 4184, as recently marked up by the House Science, Research and Technology Subcommittee. That measure contains an additional $4 million for SEE. These additional funds would bring the SEE Fiscal Year 1987 authorization to $93 million. We believe that this increase of nearly 7 percent above Fiscal Year 1986 funding is a sound investment. The long-term gains of basic scientific research clearly will not be realized if the scientists and engineers of tomorrow are not adequately prepared today.

ETHICAL RESEARCH ON SCIENCE AND TECHNOLOGY

APA would like to take this opportunity to commend the Members of this Subcommittee and NSF Director Erich Bloch for actions taken to preserve long-term support of research on the ethical questions often raised by scientific advances. APA encourages NSF to continue its new mode of distributed funding for ethics and values research, and suggests that funding for these activities be raised from $500,000 in Fiscal Year 1986 to $1 million in Fiscal Year 1987 (the activity's level of support before the FY 86 budget cut). APA is particularly pleased that the Foundation is providing for the review of all projects in this area by an ethics advisory committee. It is essential for NSF to ensure that these studies will be properly coordinated and of high quality. As new mechanisms are being created to support these studies, APA encourages Congress to continue overseeing NSF support of research on scientific ethics and values.

BASIC RESEARCH AS AN INVESTMENT

The Administration has proposed significant increases for NSF-supported research—even in the face of large federal deficits—with the conviction that investing in basic scientific research will improve our competitiveness internationally and strengthen our scientific base at home. At least eight major studies released in the last three years recommend strong support for basic research. Groups recommending increased Federal support for basic research (which is less likely to attract support from the private sector than applied studies) include the Heritage Foundation, the National Association of Manufacturers, the AFL–CIO, the Business Roundtable, and Georgetown University's Center for Strategic and International Studies.

The behavioral and social sciences have a critical role to play in these efforts to revitalize the nation's economic and technological base. While our international competitors have been quick to recognize these contributions, increases in productivity that could be realized by modifying organizational structures and personnel policies have too often been passed over here in the United States. Indeed, the American Association for the Advancement of Science (AAAS), in Congressional testimony presented earlier this year, emphasized that in areas such as industrial productivity and innovation, "research findings from the behavioral and social sciences frequently are of greater consequence than those from the physical sciences and engineering."

While technological advances must figure prominently in revitalizing this nation's industrial base, human, social and institutional factors can play an even more important role. This is true whether one is addressing the conduct and management of research, the dissemination and marketing of new technical products, or the implementation of new manufacturing processes. A few examples follow:

(1) Employee turnover is a costly problem in both the public and private sectors. Even when effects on the productivity of the organization have been disregarded,

behavioral scientists estimate that it will cost between $400 and $4,700 (depending on the nature of the position and the organization) to replace each departing employee. A major study of 20 different experiments designed to reduce employee turnover (McEvoy and Cascio, Journal of Applied Psychology, 1985, Vol. 70, No. 2, 342-353) found that programs aimed at "enriching" jobs on average reduced employee turnover by 17 percent. Thus for every 100 employees that an organization has in a particular job category, enriching or redesigning job tasks could save an average company between $6,800 and $79,900 per year.

(2) A global study on the impact of organized programs designed to increase employee productivity in the workplace found that the average worker's productivity did, in fact, increase significantly (Guzzo, Jette and Katzell, Personnel Psychology, 1985, Sum, Vol., 38(2), 275-291). This study analyzed the findings of 100 separate studies covering 11 types of psychologically-based organizational interventions. Not all interventions were equally effective. The most powerful strategies, it was found, were in the areas of employee training and goal setting. Surprisingly, supplying employees with increased financial incentives did not reliably lead to increased productivity. The effects of worker incentive programs varied widely the study found, sounding a warning to those who depend solely on increasing compensation to boost productivity.

(3) Research conducted in the United States following the Second World War demonstrated techniques to increase the quality of mass produced units through increasing employee decisionmaking (Coch and French, 1948, American Psychologist, 1982, Vol. 37, No. 7, 737-746). This social technology led to the training of production workers in rudimentary research design and statistical techniques enabling them to monitor and become more involved in the production process. This concept, which was originated in the United States, evolved into the unique Japanese technology, "quality control circles." The high overall quality of the Japanese automobile industry is attributable in part to the effects of quality control circles.

While there is a great need to conduct more research on the development of strategies and conditions critical to more efficiently utilizing the nation's human resources, such studies, for the most part, are not supported at the National Science Foundation. Primarly, NSF funding for the behavioral and social sciences has gone to support individual investigations pursuing the fundamental questions on human behavior and mental functioning. This is the type of work which forms the base for studies on improving productivity such as those already cited in this testimony. For example, social psychology research projects at NSF last year included basic studies on group opinion changes, social perception and the processing of social information. Findings emerging from these studies may be used to guide other behavioral scientists in devising strategies to be used in motivating employees. Similarly, basic research in the cognitive sciences last year included fundamental studies on knowledge acquisition, decision-making, and memory. Clearly advances in these areas are key to developing new, more effective educational and training strategies.

It is in the support of such basic, fundamental research in which NSF has the greatest role to play. Simply put, without the provision of additional financial inducements, support for these studies is rarely available from the private-sector since the ultimate payoff for these basic studies is often not readily apparent. Currently, behavioral and social science research is specifically excluded from the law which grants tax credits to industry in return for their support of basic scientific research.

Thank you again for the opportunity to present this statement. It has focused on the contributions that the behavioral and social sciences make to increasing the nation's productivity and international competitiveness. Of course, psychologists engage in many other areas of research. Their activities form an impressive array of inquiry which ranges from purely physiological phenomena to purely social phenomena and includes such diverse topics as normal and abnormal brain growth and development; educational processes such as learning and memory; the study of social institutions and interactions; survey research; and the development of standardized tests with many applications in both the public and private sectors.

STATEMENT OF THE SOCIETY FOR AMERICAN ARCHAEOLOGY

Mr. Chairman and Members of the Committee, the National Science Foundation plays a major role in basic archaeological research. From the development of regional centers for archaeological analysis to individual research grants, the National Science Foundation is responsible for generating basic archaeological methods and theories.

Basic archaeological research can produce significant spin-off benefits. For example, prior archaeological work has fostered the rediscovery of long forgotten prehistoric plants and resources which have contemporary practical applications. Research on two prehistoric seed bearing plants, Amaranth and Chenopodium is being conducted in Kansas, Nebraska, Iowa and several other states. Both of these ancient plants provide a compliment of the essential amino acids necessary for the body to synthesize proteins, as well as high levels of calcium, iron and other essential vitamins, offering valuable potential as worldwide food sources. Obsidian glass, found to be used for a variety of prehistoric tools, has been used successfully as surgical blades in delicate eye, heart, lung and nerve surgery. Obsidian surgical incisions promote a rate of post-surgical healing time half that of current surgical scalpel incisions. In addition, archaeological sites provide evidence of the impact of human activities resulting in erosion, sedimentation, soil disturbance, depletion, and enrichment. These types of studies can serve as a means of addressing modern soil management programs.

The Administration's budget request for FY 1987 at the National Science Foundation would enable continuation of existing programs. It could also enable modest efforts to fund regional integration studies based on the extensive number of research reports generated by other agencies in the course of their own archaeological programs.

Thank you for the opportunity to present this statement in support of the important archaeological work done at the National Science Foundation.

STATEMENT OF THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS [IEEE]

On behalf of the Aerospace and Engineering Research and Development Committees of the Institute of Electrical and Electronics Engineers, Inc. [IEEE], it is a pleasure to submit our views on the proposed budget for the National Science Foundation and the National Aeronautics and Space Administration for fiscal year 1987. The IEEE is the world's largest technical professional society, with over 226,000 members in the United States alone.

I. FUNDING FOR THE NSF IN THE FISCAL YEAR 1987 BUDGET

For Fiscal Year 1987 the President's request for the National Science Foundation represents an increase of approximately 4 percent from the presequestration level of $1.619 Billion to $1.686. Research and related activities would increase $126.795 Million to $1.479 Billion. Funds proposed for the Engineering Directorate would reach $185.47 Million, an increase of approximately $22.9 Million over presequestration FY 1986 numbers. The Engineering Directorate continues to represent approximately 11 percent of the proposed total for the NSF.

In general we find the budget encouraging, under the current budgetary constraints. The overwhelming bulk of the increase was targeted toward the Engineering Research Centers. We realize that it is often necessary to have a sharp budgetary rise in a new program area to enable full implementation of the concept on a timely basis, and we certainly do not begrudge the fact that the whole of the Engineering Directorate has not increased by the same percentage. Our concern is that this skew in the funding increase pattern is a net reduction in support for the individual award program. Rather, we urge that in the future, distribution of funds should place more emphasis on the individual to restore the program balance. I will now discuss our rationale for this position.

Engineering research centers and individual faculty research

The National Science Foundation should be strongly encouraged to actively promote basic engineering research by individual faculty members, while supporting technologically relevant applied R&D efforts through the Engineering Research Center [ERC] program.

The ERC concept represents a major new thrust by the NSF to create innovative research centers which can make real progress in areas that can contribute to the industrial competitiveness of U.S. industry.

While the ERCs offer significant potential to stimulate the competitiveness of selected areas of U.S. industry that are crucial to the nation's economy, they represent a small percentage of the nation's engineering faculty and students. There are 11 ERC programs at the present time which represent a small percentage of the 227 engineering schools with graduate programs. Even at the ERC schools, the ERC program involves only a small portion, perhaps 10 percent, of the graduate engineering enrollment. We must also assure potential funding for individual research by faculty at schools without an ERC as well as those schools with an ERC.

Each ERC, as with all major university and university/industry research efforts, evolved from individual faculty research projects. We believe that the NSF must continue to encourage and enhance such research.

We strongly recommend that you support a continuing commitment by the NSF to individual faculty efforts. In addition, we encourage the continued development of the ERC program. To ignore the importance of the cross-disciplinary research conducted at the ERCs is to penalize the competitiveness of U.S. industry. We strongly recommend that the NSF support a balanced research program in which the individual researcher and the ERCs play synergistic roles.

Philosophy of basic research

It is widely accepted that conclusions of basic scientific research lead to applied research and the development of technological goods and services. In fact, that is not always the case. Two examples illustrate this: the magnetron and the transistor. In 1939, the British had laboratory models of magnetrons but the basic theory was not understood. That theory, developed at M.I.T. when the British brought models and their problems to the U.S., made possible the development and production of practical microwave radar for our joint use in World War II, and led to the spawning of the microwave industry to include such diverse products as communications links and microwave ovens. The point-contact transistor demonstrated at Bell Laboratories in 1946, although the result of an established and multiple-effort research culture, appeared before the basic theory of semiconductor amplification was understood. Again, only after that demonstration of a new technique was research effort conducted to determine the basic theory that led to translating the technique into practical applications. That activity also spawned major industries, within which the interplay of basic engineering and science research continues to the present day, as with very large-scale integrated circuits (VLSIC).

The point of these examples is that basic research must take place in engineering as much as it does in science. Neither "always comes first". The two complement each other, and both are necessary to the continued technological and industrial growth of the U.S.

Engineering research spans the range from basic physical phenomena to large-scale systems. In electrical engineering research, this includes materials, electronics, electrical techniques and devices, characteristics of computer hardware and software, combinations of devices and software into systems, and the effects of systems on man and the environment. Because of this large spectrum of endeavors, engineering research frequently requires teams of professionals. It cannot always be done by individuals. A plurality of approaches is necessary to cover the spectrum.

The objective of engineering research is the ultimate application of experimental and analytical results to public needs. It is not undertaken merely for the sake of knowledge, nor is it necessarily focused on an immediate product or service. As in the cases of the magnetron, directed initially at radar and the transistor, intended to substitute for the vacuum tube amplifier, it is impossible to tell whether or where the payoffs of such research will come. But come they will.

Support commensurate with economics and populations

Electrical Engineering is the largest discipline among all of engineering. It is central to the industrial and economic health of our nation. As America's industries are currently envolving, electrical engineering is increasingly being called upon to provide the high-technology "underpinning" essential for their future efficiency, competitiveness and growth. Currently the electrical and associated industries are a major contributor to both our gross national product and to the balance of trade.

Reflecting this, Electrical Engineering Departments at our nation's colleges and universities tend to be the largest of all the engineering departments. The demand for electrical engineers is extremely high. However, the electrical industry is at risk. Much of our activities are subject to intense foreign competition. We need a strong electrical engineering research program at our nation's colleges and universities to meet this challenge.

We find that, during the past few years, NSF funding at electrical engineering departments has eroded. We urge you to support a strong vigorous electrical engineering program at NSF, especially at the individual innovator level.

In summary, we find the NSF budget encouraging. We support the initiative to develop several Engineering Research Centers and we realize the necessity for a sharp budgetary rise in a new program area to enable full implementation of the concept in a timely manner. However, we urge that in the future, distribution of funds should place more emphasis on the individual investigator to restore program balance, and to further enhance the synergistic roles played by the individual researchers and the Engineering Research Centers.

II. FUNDING FOR NASA IN THE FISCAL YEAR 1987 BUDGET

Unlike previous years when the IEEE has been asked to present its views on the NASA budget, we along with many others share the difficult task of reviewing a budget document which is based on assumptions that unfortunately in large part are no longer appropriate. The official FY 1987 NASA budget proposal would have been, even under different circumstances, a very tight one. The request of $7.694 billion represents minimal growth from the FY 1986 Appropriations of $7.656 billion and the FY 1985 Appropriations of $7.552 billion. In fact, if one looks back at past NASA budgets, for FY 1986 NASA accounted for about 0.7 percent of the total Federal budget versus the mid-1960s when it was about 5 percent of the budget.

In terms of dollar levels, the NASA budget numbers are not encouraging, especially when you confront the additional reduction of $323 million facing NASA for FY 1986 due to the Gramm-Rudman-Hollings cutbacks. However, there are some positive indications in the budget that suggest NASA is moving back more to its traditional role as an R&D agency. For example, from FY 1985 to FY 1987, NASA's R&D activities would increase from $2.47 billion to $3.00 billion (a 21.7% increase) while its space flight and operational budget requirements decrease from $3.59 billion to $3.07 billion (a 14.6% decrease). Continued vitality in NASA's R&D efforts are crucial to its future and the future of the United States.

Mr. Chairman, with regard to the future I would like to share with the Subcommittee a paper recently prepared by IEEE that we submitted to the National Commission on Space. It suggests some important goals toward which the U.S. civilian space program should be directed. I will summarize some of the key goals and attempt to relate them to the question of priorities for the FY 1987 NASA budget.

The main IEEE recommendations which pertain to the current NASA budget are as follows:

We should see earth systems science and space technologies developed so that space can be used:

We must sharply reduce the unit cost of acquiring, operating and using space assets.

We should open up space travel to the general public.

Our universities should now begin to acquire their own independent, privately supported in-space research facilities.

We must spur space infrastructure acquisition and use by our private sector.

The first goal emphasizes the importance of developing space technologies to benefit the world's population through greater understanding of our universe and application of that knowledge to practical purposes. Much of what is proposed in NASA's space sciences and applications program fits this objective. IEEE supports the various physics, astronomy and planetary efforts already underway, and hopes they will get high priority for launch once the shuttle returns to operation.

Our first recommended goal leads IEEE to strongly support the NASA budget requests in materials processing that could lead to new biological materials and medicines as well as vital inorganic materials such as new semiconductors. We also support such environmental programs as the Upper Atmosphere Research Satellite [UARS] program and the proposed Ocean Topography Experiment [TOPEX].

The IEEE also strongly endorses the NASA Communications program involving search and rescue, mobile communications and the Advanced Communications Technology Satellite [ACTS] program. Two years ago, because of our unique technical expertise, IEEE was asked by Congress to comment on the benefits of ACTS in maintaining U.S. leadership in satellite communications. We see nothing in the foreseeable future that will eliminate global use of satellites for communications purposes. Notwithstanding the advances in fiber optics, satellites will have unique technical and market features that will continue to make them competitive. The question then is will these satellites and associated ground systems be U.S. or foreign. The ACTS program will help to maintain a U.S. domination in this area. The resultant economic benefits would stay here and not go abroad. Why forego this capability, particularly when now, two years later, we have already obligated approximately 50 percent of the program costs?

The second IEEE goal involves the need to sharply reduce the unit cost of reaching and operating in space. This objective suggests that first and foremost, we must move forward at the earliest appropriate time with our shuttle program. The budget implications in this area are significant and most uncertain at this time. In the past, there was doubt that a four-orbiter fleet could accomplish the required space missions and maintain the 24-28 launch rate per year. This Subcommittee as well as others in Congress advocate purchase of a fifth orbiter. In testimony before Congress dating back to 1982, IEEE also lent its support for such an acquisition. The need for one replacement orbiter is clear. Perhaps as some suggest, two are justifiable or at least a four-orbiter fleet with backup ELV capacity is the appropriate approach.

Apart from the purchase of additional shuttles but related to the question of access to space, IEEE supports the NASA request to participate in the Administration's proposed "aerospace plane" program. NASA's participation is consistent with its role in aeronautical R&D and the prospects for advances in this technology could significantly help reduce the access costs to low earth a manned space station along with unmanned platforms will provide a quantum leap in the United States' ability to work in space. This ensemble of capabilities could over time also lead to lowered costs in space operations.

The space station is an important national objective if we are to maintain world leadership in space. At the same time, this development should not come at the expense of space science and applications efforts.

If the costs associated with reaching and working in space are lowered, this would lead to another goal we enunciated, opening space travel to the general population. In time, this will occur and its evolution could be a useful market incentive for further cost-reduction efforts.

Mr. Chairman, the role of the private sector in expanding U.S. presence in space is a key IEEE theme. This could be accomplished through the traditional customer-producer relationship. It also could be enhanced through NASA and Administration policies that would minimize high cost risks and reduce policy uncertainties. Private sector partnerships with universities could be another promising avenue leading to enhanced business interest in space. NASA has taken some steps in all of these areas already, and through their space commercialization program would expand their activities. We encourage the Subcommittee to support their efforts.

In summary, IEEE's view of the NASA budget is that:

It should show growth in R&D efforts;

It should maintain ongoing science and applications programs, including ACTS;

It should provide new starts for space station, TOPEX and transatmospheric R&D;

It should provide for continued expansion of space commercialization initiatives; and

Our space transportation system must be enhanced by at least one shuttle orbiter.

There is one concluding observation regarding the NASA budget for FY 1987. The budget requirements for "getting healthy" after the Challenger accident could lead to an unhappy circumstance for other NASA programs. Once NASA and Congress determine the causes of the accident and the required "fixes", the resultant costs should not come at the expense of existing NASA initiatives. The overall program is suffering already. The accident should be treated as a one-time occurrence, and, for budgetary purposes, as a supplemental request. Our civilian program must maintain its balance of initiatives and those initiatives need to be protected.

We would be pleased to provide you with any further information we can that would be helpful in your deliberations.

STATEMENT OF JON W. FULLER, PRESIDENT, GREAT LAKES COLLEGES ASSOCIATION

Mr. Chairman, I am Jon Fuller, President of the Great Lakes Colleges Association. I am pleased to have been invited to submit a statement to this committee as you consider reauthorization of activities of the National Science Foundation. I am representing the twenty-five liberal arts colleges which are members of the Great Lakes Colleges Association and of the Associated Colleges of the Midwest.[1] Reed College in Oregon and Connecticut College also join in supporting our position.

The original authorization of the National Science Foundation gave it a dual responsibility both to support the most promising basic research and also to provide for our future scientific capacity through the support of science education at the undergraduate and pre-college levels. Our national security and our economic well-being rest on our continued excellence, both in current research, and in development of an adequate number of scientists, teachers of science, and technicians for the future. We are pleased to see that, after a period of serious and dangerous neglect, the National Science Foundation has renewed its commitment to this second part of its mission, "the development of properly educated and trained people, the human resources pool that provides the scientists and engineers for the future," as the NSF Director, Mr. Bloch, aptly put it in introducing the Foundation's fiscal 1987 budget proposals.

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[1] The Great Lakes Colleges Association is a consortium of twelve undergraduate liberal arts colleges: DePauw, Earlham, and Wabash in Indiana; Albion, Hope, and Kalamazoo in Michigan, and Antioch, Denison, Kenyon, Oberlin, Ohio Wesleyan, and the College of Wooster in Ohio. The Associated Colleges of the Midwest includes thirteen undergraduate colleges: Colorado College; Knox, Lake Forest, and Monmouth in Illinois; Coe, Cornell, and Grinnell in Iowa; Carleton, Macalester, and Saint Olaf in Minnesota, and Beloit, Lawrence, and Ripon in Wisconsin.

It is extremely important that the process of science education and the education of scientists be seen as continuous. The undergraduate years represent a crucial phase in this process, the last point at which qualified students can choose careers in science—and unhappily, the time during which significant numbers of qualified students are choosing not to purse careers in science. A declining proportion of American undergraduate students express an intention to major in science, and each year fewer baccalaureates are being awarded for the completion of science majors. This is happening at a time when every projection of our future needs indicates that we will need larger numbers of scientists, teachers of science, and appropriately trained technicians to sustain our scientific and economic activity. This decline in interest in scientific careers extends to the graduate schools, where we have seen a significant drop in the number of new Ph.D.'s they award each year in the physical sciences, mathematics, and engineering. A real danger to us as a nation is the fact that the number of American citizens among those science Ph.D.'s has declined even more sharply than the total numbers would suggest. An increasing proportion of the graduate school enrollment in the sciences and particularly in engineering is now made up of foreign nationals. As NSF Director Bloc recently put it there is a real danger that pursuing a Ph.D. in the physical sciences and engineering is "becoming an un-American activity!"

The colleges which I specifically represent, and others like them across the country, take pride in the fact that our science enrollments have not declined. We also take pride in the continuing contributions of these institutions in sending their graduates on to complete Ph.D.'s in the sciences. That contribution is particularly striking when one takes account of the smaller institutional size of most of these colleges, compared to the large universities. I have attached to my testimony a summary of recent research by Dr. Carol Fuller of our staff which identifies the most productive undergraduate sources of Ph.D.'s as measured by the percentage of their graduates going on to complete those degrees.

One response to this situation must be to support the success of these colleges which have managed to sustain undergraduate interest in the sciences. But it is also important to look at the undergraduate experience across the whole spectrum of higher education institutions, and to strengthen the quality of science instruction during those very important four years.

Because the production of scientists, teachers, and technicians is a continuous process, science instruction in the elementary and particularly in the secondary schools must also command our attention. The colleges with which I work most closely are finding a great range in the quality of preparation in mathematics and science among freshmen who come to us. Some of it is really very good. But the overall grade must still be rated as "poor." A significant part of the problem is that we are losing qualified secondary school science teachers, drawn away by larger salaries and more attractive professional opportunities. A significant part of the responsibility for dealing with the situation in our elementary and secondary schools certainly lies at the local and state level. That is particularly true in terms of trying to deal with the difficult issues of appropriate levels of compensation for teachers generally, and specifically for those in fields like the sciences and mathematics. But the federal government can have an important and useful role in upgrading and sustaining the qualifications of those who do chose careers in teaching science in our elementary and particularly in our secondary schools. In-service and summer institutes, now being sponsored by NSF, are certainly useful. Cooperative links between schools and colleges and universities are also very helpful, and we hope that NSF will be more active in encouraging and supporting those kinds of linkages. Because such an important part of the problem seems to be sustaining the sense of professionalism for teachers of science, we need to look carefully at programs of recognition and encouragement for these important people. One promising development, now being supported on a very experimental basis by NSF, involves including secondary teachers in research activities in colleges and universities, particularly during the summer, as a way of recognizing and sustaining their commitment as scientists.

Let me turn now to the specific needs at the undergraduate level. The National Science Board last year established a Task Committee on Undergraduate Science and Engineering Education to address problems of science at the undergraduate level. The Task Committee has now issued its report. We enthusiastically endorse its recommendations on action to be taken to bring NSF funding for undergraduate science support to an appropriate level by fiscal 1989. From the Executive Summary of the final report we list the program areas of highest priority and indicate the distribution of funds appropriate to their complementary character:

Laboratory Development—$20 million.
Instructional Instrumentation and Equipment—$30 million.
Faculty Professional Enhancement—$13 million.
Course and Curriculum Development—$13 million.
Comprehensive Improvement Projects—$10 million.
Undergraduate Research Participation—$8 million.
Minority Institutions Program—$5 million.
Information for Long-Range Planning—$1 million.

The National Science Foundation now offers two programs which can assist colleges and universities in meeting their equipment needs. The first of these is the College Science Instrumentation Program. There have been far more quality proposals to this program than it has been possible for NSF to fund. The $2 million increase proposed by NSF for CSIP in fiscal 1987, which raises the program's budget to approximately $7.5 million, is a step in the right direction although the recommendation of the NSB Task Committee for $30 million in fiscal 1988 more realistically addresses the need. Given the number of competing institutions now eligible, we urge that the 1987 competition for these funds remain open. Mr. Bloch's proposed $3 million "set aside" for engineering departments in undergraduate and Ph.D.-granting institutions would leave less for awards to undergraduate institutions than in either of the program's first two years.

It has also been possible to support research instrumentation (which at any good undergraduate college always has instructional uses as well) through the research directorates' funding of proposals under the Research in Undergraduate Institutions Program. Instrument support has been one of the most valuable products of this program, and we certainly hope that it will be sustained.

A second need for undergraduate institutions is research opportunities for their scientists. This is now being provided primarily through NSF's Research in Undergraduate Institutions Program. Frankly, there have been some problems because of the highly decentralized nature of this program's administration. Some directorates have been very responsive to RUI priorities, while staff and reviewers in other parts of the agency continue to reflect not only a lack of understanding but even hostility to the idea that good research can be done by scientists whose primary focus is on the teaching of undergraduates. We hope that this committee will join us in continuing to press NSF leadership for accountability in actually delivering on the promises of the RUI program.

Supporting of research being done by faculty members who are actively engaged in teaching undergraduates simultaneously produces good and needed research results and also uniquely important education for future scientists. The research done by scientists at undergraduate institutions can be just as good as that done in any setting across the country. Because of its scale and pace, research conducted at undergraduate institutions can make uniquely valuable contributions to science. It is important, however, as the RUI guidelines try to make clear to reviewers and staff members, to recognize that work done by a scientist with major undergraduate teaching responsibilities must inevitably come at a slower pace and that the quantity of published results will be less, although the quality can be competitive with that of scientists whose primary responsibility is research.

There is another advantage in research which is done by scientists at undergraduate colleges: it is typically carried out as an extension of teaching, involving the most promising undergraduates. This is one of the reasons that support of research by faculty at undergraduate teaching colleges has a double value: the quality of the research itself, and the contribution it makes to the education of some of our best future scientists. In background materials done for a conference held at Oberlin last summer, which brought together 48 good liberal arts colleges with a strong record in science productivity, it was noted that the science faculty at those institutions had produced approximately 7,000 articles in the past 5 years, and that a third of those had been co-authored with undergraduates.

One of the most valuable programs of the NSF's Science Education Directorate was the Undergraduate Research Participation program. Unfortunately, it was abandoned by the agency several years ago, as part of its effort to shed that important part of its overall mission. As that trend is being reversed at NSF, we are pleased that funding for undergraduate research participation is back on the agency's agenda. We wonder why the Science and Engineering Education Directorate is not being called upon to administer this program, with the education of undergraduates as its principal purpose; URP was an exemplary program, both in review and operation, when it was operated under that aegis earlier. The fiscal 1987 budget summary mentioned plans to support bringing together "small groups of students to participate in the conduct of research." There appears to be an interest in having that take place at major research laboratories, and that certainly is one appropriate way of organizing undergraduate research opportunities. It is also important to fund such activities at undergraduate campuses, so that some of the research work can go on during the academic year, and not just in the summer as part of a special program. As Mr. Bloch has noted, "once students enter their third or fourth years, the best way to prepare them to undertake graduate work is by increasing opportunities to participate in research activities."

The Associated Colleges of the Midwest and the Great Lakes Colleges Association are currently conducting a survey of past participants in the URP program, to identify the influence of that experience in their subsequent careers. When that survey is completed, we will certainly report its findings to this committee as well as to the Foundation. The preliminary and essentially anecdotal results are, not surprisingly, a strong endorsement of the value of research experience during the undergraduate years.

It has been possible to support undergraduate research experience as part of the RUI program. There has been great unevenness in the agency, however, in the degree of understanding by staff and reviewers about the value of that element of any research proposal.

The NSF is on the right track in its plans to resume support for undergraduate research participation. We hope that this will have your committee's full support. It represents an important and definitely cost-effective investment in our future scientific resources.

One area which is still not being adequately addressed by any NSF efforts involves the broader professional development of science faculty members who teach at undergraduate institutions. Opportunities to do research are an important part of professional development for those scientists whose primary responsibilities involves the teaching of undergraduates. But they also need periodic opportunities for professional renewal. They need to work with and consult with scientists at larger laboratories, as a supplement to the research activity which they can carry on there and on their own campuses.

Faculty at undergraduate campuses are called upon to teach a broader range of courses than are colleagues at larger and more specialized institutions, and they have special needs to keep up with a wider field of knowledge. The Science Faculity Fellowships at one time filled this need by providing faculty, who did not teach in research institutions, with support to spend time in an academic or industrial research setting working on projects directly related to improving their teaching. We are pleased to see NSF recognition of this need in the fiscal 1987 budget summary, which included a promise that "traditional activities such as research sabbaticals, participation in industrial research, and special short courses and workshops will be supported." The Research Opportunity Awards, which are being advertised more vigorously by NSF, provide one type of opportunity for faculty members at undergraduate colleges to have the professionally renewing experience of being part of research activities at a larger research laboratory. But more general and flexible support is also needed. We hope that NSF and this Committee will look carefully at the successful programs of the past—particularly the Science Faculty Fellowships—as models for the ways to carry on this important element in the support for undergraduate science.

For next year, the NSF is proposing a new program, focused on the needs to recruit larger numbers of minority students into the sciences, which will involve funding of Minority Research Centers of Excellence. We think this idea, successful in the past as Resource Centers for Science and Engineering, has promise to be extended to other undergraduate institutions. The general idea is to provide sustained NSF support to build on ideas of existing strength. Those can then be used as models and resources by other institutions whose programs are still building.

We are gratified that NSF has in its budget document noted its intention in fiscal 1987 to serve more of the needs of undergraduate science education. We eagerly await details and reassurances about the administration of these initiatives. The Science and Engineering Directorate has useful connections with the undergraduate community. Their involvement could contribute to the success of these initiatives, as proven by the popular College Science Instrumentation Program [CSIP].

We believe that this Congress and the Foundation should also look seriously at the possibility of a program of challenge grants to assist institutions in raising the significant capital which is needed to restore various facets of the undergraduate scientific base. Such challenge grants have worked very well at the National Endowment for the Humanities. They provide excellent leverage for the Federal dollars invested.

One general point about the operations of the National Science Foundation and its responsiveness to the needs of undergraduate institutions needs to be made: the Foundation's advisory committees and review panels include very few scientists from undergraduate institutions. It seems clear that many of the problems in the actual execution of NSF's new and welcome efforts to assist undergraduate education come from a lack of understanding about the realities of science in such institutions. The Director, Mr. Bloch, has publicly acknowledged the need to increase significantly the numbers of scientists from undergraduate institutions who seve on these committees and panels. But actual progress seems painfully slow, and this is a real impediment to carrying forward the Foundation's new and very important emphasis on the undergraduate sector of the scientific enterprise.

A particular concern is the membership of the National Science Board. When that group, with urging from the Congress, turned its attention to undergraduate science early last summer, it was necessary to recruit an outside member for their Task Committee (President James Powell of Franklin and Marshall College) because no member of the National Science Board had direct experience with science at undergraduate institutions. It is clear that President Powell made a vital contribution to the work of that group. The continued presence of scientists with undergraduate college backgrounds in the deliberations of the National Science Board would ensure that we do not again see this important part of the Foundation's mission neglected, and that the efforts to carry it forward are indeed appropriate and effective. We ask this committee to urge the National Science Foundation to see that appropriate candidates are nominated to fill a certain proportion of the seats on the National Science Board, so that this gap in its membeship experience is filled. Please also press NSF to carry through on the commitment to add qualified scientists from undergraduate institutions to the other Foundation advisory committees and review panels as well.

We are delighted that this committee and the National Science Foundation have, by their renewed attentin to issues of undergraduate science, joined in bringing about important and overdue changes in emphasis and priority for our federal science policies. We are prepared to cooperate in any way we can to provide you with the information you may need to evaluate this aspect of the National Science Foundation's mission as you consider reauthorization of its activities for the years ahead.

I would be happy to answer any questions which members of the committee may have.

ATTACHMENT.—LEADING UNDERGRADUATE SOURCES OF SCIENCE PH.D.'S ADJUSTED FOR INSTITUTIONAL SIZE

Institution	Total	Ratio
California of Technology	1,781	39.2
Harvey Mudd (CA)	247	39.1
Reed (OR)	766	20.0
Massachusetts Institute of Technology	5,141	19.9
Chicago (IL)	2,592	16.6
Swarthmore (PA)	975	14.4
Cooper Union (NY)	586	13.4
UC-San Diego (CA)	325	12.4
New College of the U. of South Florida	48	11.7
Haverford (PA)	415	11.4
Webb Institute (NY)	47	11.2
Rice (TX)	1,192	10.8
Harvard (MA)	3,527	10.3
Oberlin (OH)	1,347	10.3
Pomona (CA)	713	9.2
Brandeis (MA)	578	8.7
UC-Riverside (CA)	709	8.7

ATTACHMENT.—LEADING UNDERGRADUATE SOURCES OF SCIENCE PH.D.'S ADJUSTED FOR INSTITUTIONAL SIZE—Continued

Institution	Total	Ratio
Carleton (MN)	631	8.7
Eckerd (FL)	77	8.5
Rensselaer Polytechnic Institute (NY)	1,819	8.5
Wabash (IN)	324	8.4
Amherst (MA)	642	7.9
Cornell U. (NY)	4,213	7.9
Antioch	620	7.8
UC-Irvine (CA)	253	7.8
Johns Hopkins (MD)	1,207	7.8
Polytechnic Institute of New York	935	7.6
Princeton (NJ)	1,765	7.6
Grinnell (IA)	450	7.3
Wesleyan (CT)	511	7.2
Carnegie-Mellon (PA)	1,422	7.0
New Mexico Institute of Mining	111	7.0
Kalamazoo (MI)	307	6.7
Columbia (NY)	2,553	6.6
Yale (CT)	1,996	6.5
UC-Santa Cruz (CA)	192	6.4
CUNY: City College (NY)	4,990	6.2
SUNY: Stony Brook (NY)	597	6.2
Wooster (OH)	527	6.2
Case Western (OH)	1,751	6.0
Philadelphia College of Pharmacy (PA)	252	6.0
Stanford (CA)	2,401	6.0
Williams (MA)	507	6.0
Bryn Mawr (PA)	276	5.9
Earlham (IN)	308	5.9
Franklin & Marshall (PA)	554	5.9
Brown (RI)	1,388	5.8
Radcliffe (MA)	469	5.8
New School (NY)	57	5.6
Stevens Institute (NJ)	359	5.6
Worcester Polytechnic (MA)	400	5.6

Ratio-average science Ph.D.'s divided by average baccalaureate degrees awarded.
Science Ph.D. totals reported by the National Academy of Sciences. Sciences include Empirical, Life, and Social Science fields. Baccalaureate totals reported by the National Center for Educational Statistics and the American Council on Education.
Calculations based on Ph.D.'s conferred, 1951-1980, and bachelor's degrees awarded, 1946-1976.
(in a few cases, the numbers reported here differ from previously published numbers because of adjustments in baccalaureate data.)

STATEMENT ON BEHALF OF ASSOCIATION OF AMERICAN UNIVERSITIES, NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES, AMERICAN COUNCIL ON EDUCATION, ASSOCIATION OF GRADUATE SCHOOLS, AND COUNCIL OF GRADUATE SCHOOLS IN THE UNITED STATES

Mr. Chairman and members of the committee, we appreciate the opportunity to discuss the proposed budget of the National Science Foundation.

CONVERGING BUDGETARY PRESSURES

This year is marked by a pervasive sense of vulnerability by universities because several essentially unrelated policy lines seem to be converging. Let us briefly describe those lines and explain why they should be of interest to Members whose responsibilities include the maintenance of America's capacity for science and science education.

Overall reductions

The first set of policies to impinge on universities are those set in motion by deficit reduction pressures. NSF stands out among federal agencies for its proposed increase for FY 1987. Virtually every other program on which universities rely is slated for significant reductions. The proposed cuts in other areas will strike heavy blows at mainline university activities, forcing either reductions in institutional programs or the increased subsidizing of those activities by other elements of the university.

Indirect cost recovery

Second, the proposed revisions to OMB Circular A–21 which would cap particular components of indirect cost recovery, will hit the budgets of research universities heavily. If those rules take effect as proposed, losses in the millions of dollars a year will be incurred by individual institutions, and virtually all universities will suffer noticeable reductions.

Tax reform

The third line of policy converging on universities makes the effects of the first two even more devastating. The tax reform bill that passed the House last year contains a number of provisions that will simultaneously cost universities more money and severely undermine their ability to raise money from private philanthropy. The effect of the adopted provisions—together with the first two policy decisions—must be taken into account by anyone who cares about the health of America's universities or the nation's capacities in science and technology.

Now you may ask, What is to be done? The answers for this year are clear enough. They are, where possible, as with NSF, to support budget levels that will help sustain the enterprise through a difficult period; to help prevent arbitrary, damaging, and non-negotiated changes in the principles that govern indirect cost recovery by urging OMB to sustain genuine negotiations with affected parties; and to oppose changes in the tax code that would lessen the incentive for private philanthropy and thereby make it less likely that private efforts can compensate for the inevitable diminution in federal programs.

We are aware, Mr. Chairman, that these opening remarks have gone far afield from the testimony that we would ordinarily give on this occasion. We have done so because it seems to us evident that when you have finished work on this NSF budget, you will, as Members of Congress, face an agenda that is even more important to science and to universities than the annual budget of any single agency can be. As you approach those larger issues, we urge you to bring to them the same purposes and perspective that move you to believe that the work of the National Science Foundation is worth your support.

THE RESEARCH PROGRAM OF THE NATIONAL SCIENCE FOUNDATION

Let us now turn to the specifics of the Foundation's Budget request, and begin by addressing the research budget.

Top priorities

First, we congratulate Mr. Bloch, Director of the Foundation, and the National Science Board for presenting to the Congress a strong, reasonable, and generally well-balanced budget for the NSF. This Budget request clearly recognizes that even in these difficult times, we cannot afford to reduce our investment in academic science and engineering. Sustained budgetary stringency requires that we make difficult choices in order to support the two ingredients essential to our welfare: the talent of our young people and our expanding body of new knowledge. We must take those necessary steps to encourage able and interested students, especially underrepresented minorities and women, to pursue undergraduate and graduate programs in academic science and engineering.

When national investments in education and research are combined in the university enterprise, unique benefits result. Now, more than half of all federal basic research programs are carried out in universities and colleges; NSF alone accounts for 25% of total federal basic research funding in universities. The bond forged between education and research is the unique strength of academic science and engineering. We applaud, therefore, NSF's proposal to further expand involvement of graduate and undergraduate students in many of its research programs.

Individual investigator grants

As the promising and important initiatives announced by the Foundation go forward, it will be important to pay careful attention to the matter of balance between them and the core funding mechanism of the Foundation—the individual investigator grant. As presented, the budget sustains investment in competitive awards to individual researchers. It seeks to protect progress made in recent years to strengthen the average size and duration of foundation grants. We trust that these gains will not be compromised by the development of exciting new initiatives.

Behavioral and social sciences

One research area has posed particular concerns for the past several years: the Foundation's social and behavior sciences programs. These programs were subjected to sharp reductions in the period between FY 1980 and FY 1982. We are pleased to see that they have been making progress toward regaining their appropriate place in the NSF research budget. In FY 1986, however, that progress was reversed. The final funding level for the behavioral and social sciences was cut last year to below FY 1985 levels. We now face the prospect of renewed erosion of these fields, and that is sobering.

The FY 1987 budget proposes to restore, in current dollars, the sharp reductions imposed just a few years ago. However, in light of the cuts imposed in FY 1986, we must point out that real investment in these fields, measured in constant dollars, remains significantly below the FY 1980 level, demonstrating an erosion of about one-third in six years. We do not believe this adequately reflects an appropriate recognition of the potential contribution of research and education in these fields to our productivity and security.

Astronomical sciences

We also would call the Committee's attention to one potentially anomalous aspect of the budget request: the request for astronomical sciences. While most of the sciences and engineering research programs are slated to receive at least a measure of real growth, a reduction in constant dollars is proposed for the astronomical sciences. Because the NASA astronomical science budget also is under considerable strain this year, we believe it is timely to inquire about the combined consequences for university astronomical sciences programs of such a sharply constrained budget request.

GRADUATE FELLOWSHIPS

For many years, one of the most effective programs in helping to identify and attract young talent has been the NSF Graduate Fellowship Program. Again this year, the Graduate Fellowship Program is level funded. After making progress toward overcoming the effects of a decade of erosion, the program again is beginning to lag significantly behind market forces competing for the best young minds in science and engineering.

Education allowance

This year the cost of education allowance poses a particular problem. For more than a decade, the allowance has fallen steadily behind the actual cost of graduate education in the sciences and engineering. This year, the NSF program is proposed to take a further step backwards by reducing the cost of education allowance that accompanies each NSF fellowship from $6000 to $5250. Instead of covering even the cost of tuition, which itself fails to meet the true costs of instruction, the NSF requires host universities to subsidize the program in steadily increasing amounts. We urge that present funding levels for the cost of education allowance be sustained.

UNDERGRADUATE SCIENCE AND ENGINEERING EDUCATION

The proportion of our young people now attracted to university programs of science and engineering is declining. Looking ahead, if we continue to attract students into these fields at only the 1983 rate, we will (as a result of certain declines in the numbers of 22-year-olds) produce almost 700,000 fewer baccalaureates in these fields over the next 20 years. The National Science Foundation has a serious leadership responsibility in science and engineering education at the undergraduate level.

The Foundation is proposing only a modest increase for science and engineering activities with the exception of the College Science Instrumentation Program, increased by $2 million. In order to fund between 75 and 80 new projects, all programs are being maintained at their FY 1986 level. Although we are pleased to see an expanded commitment to education, especially in our schools of engineering, the proposed program level can be considered only the first step toward addressing the problems associated with obsolete instructional equipment and materials.

INSTRUMENTATION AND FACILITIES

The Foundation has made substantial progress in identifying and meeting the research instrumentation needs of foundation-funded investigators. Now about 20 percent of total NSF research funds is allocated to the acquisition of research equipment. We commend the Congress and the Foundation for addressing the research equipment problem.

We must point out, however, that little progress has been achieved in meeting the needs of research institutions to replace and modernize the laboratory buildings in which national research programs are conducted. Federal investment in academic research facilities has declined almost 95 percent since 1965. The backlog of investment required to meet accumulated needs is unknown, but it is clearly in the multibillion range.

The White House Science Council has recommended that the National Science Foundation undertake a special ten-year research facilities modernization program. We are encouraged by the Council's recommendation. The characteristics of the problem, its seriousness, and a federal responsibility to help fashion solutions are becoming more widely recognized. We also are encouraged that the Foundation, as directed by Congress last year, is developing a capability to assess the problem in a comprehensive way. We hope that this Committee will urge the NSF to give the facilities problem its sustained attention consistent with the recommendations of the White House Science Council.

MERIT-BASED ALLOCATION OF FEDERAL RESEARCH AND FACILITIES FUNDS

Finally, we cannot emphasize too strongly the importance to the long-term health of the Foundation's research program of resisting any attemps to earmark NSF funds for particular institutions for either research facilities or research project support. To date, the Foundation has not been affected by the kinds of earmarking activity that has recently affected the Department of Defense, the Department of Energy, and the National Institutes of Health. We urge the Subcommittee to continue to sustain scientific and technical merit as the basis for the award of scarce federal research resources.

Thank you for the opportunity to present these views.

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